JOURNAL
of
ECONOMIC ENTOMOLOGY

UNIVERSITY
OF MICHIGAN
AUG 25 1954
FORESTRY
LIBRARY

Formerly Published by the
AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

Now Published by the
ENTOMOLOGICAL SOCIETY OF AMERICA

A new organization formed by the consolidation of the two major entomological organizations in North America and continuing publication of the Journal as Volume 46, 1953.

MENASHA, WISCONSIN

AUGUST • 1953

Volume 46 Number 4

JOURNAL OF ECONOMIC ENTOMOLOGY

Published by
ENTOMOLOGICAL SOCIETY OF AMERICA
Formerly Published by American Association of Economic Entomologists
AT MENASHA, WISCONSIN

F. W. Poos, Editor, *pro tempore*, Beltsville, Md.

ERNEST N. CORY, *Interim Business Manager*, University of Maryland, College Park

PUBLICATIONS COMMITTEE

W. M. UPHOLT, *Chairman*, Savannah, Ga. Term Expires 1956

H. M. HARRIS, Ames, Iowa. Term Expires 1956

A. W. A. BROWN, London, Canada. Term Expires 1956

B. C. DICKINSON, Elkridge, Md. Term Expires 1953

CHARLES H. MARTIN, Corvallis, Oregon, Term Expires 1953

ED. A. STEINHAUS, Berkeley, Calif. Term Expires 1954

H. L. SWEETMAN, Amherst, Mass. Term Expires 1954

A bimonthly journal published on the 15th of February, April, June, August, October and December, devoted to the interests of economic entomology and publishing the official notices and proceedings of the Entomological Society of America.

TERMS OF SUBSCRIPTION. To members of the Entomological Society of America in continental U.S.A. and its possessions $4.00. Members outside of the U.S.A.—$4.50. Non-members in the U.S.A., Cuba, Mexico and Canada—$10.00. Non-members in other countries—$10.00 plus 60¢ postage. Single copies $1.75 plus postage of 10¢ per copy.

BUSINESS COMMUNICATIONS of the Society and SUBSCRIPTIONS AND ADVERTISEMENTS to the Journal should be sent to the interim business manager, Ernest N. Cory, University of Maryland, College Park, Maryland.

MANUSCRIPTS and other copy for the Journal as well as all correspondence concerning Journal content, should be addressed to the editor *pro tempore*, F. W. Poos, Agricultural Research Center, Beltsville, Maryland.

CHANGE OF ADDRESS must reach the office of the Business Manager 45 days prior to the month of issue to be effective for that month.

Entered as second class matter at the Post Office at Menasha, Wisconsin. Acceptance for mailing at special rate of postage under the provisions of Sec. 34-40, Par. (D), provided for in the Act of February 28, 1925, embodied in paragraph 4, Section 538, P. L. and R., authorized May 1, 1936

Printed in U.S.A.

ISSUED September 15, 1953

JOURNAL OF ECONOMIC ENTOMOLOGY
ENTOMOLOGICAL SOCIETY OF AMERICA
Formerly Official Organ American Association of Economic Entomologists

Vol. 46 August, 1953 No. 4

CONTENTS

Predatism by the Adult Hymenopterous Parasite and Its Role in Biological Control ..... Stanley E. Flanders 541
The Effects of Some Soil Characteristics on DDT Phytotoxicity .. R. Thurston 545
A Survey of the Mediterranean Region for the Beet Leafhopper ..... Norman W. Frazier 551
Tests with Two Systemic Insecticides on Vegetable and Field Crops in Southern California ..... H. T. Reynolds, L. D. Anderson and J. E. Swift 555
Studies of Mites and Their Control on Pecan in Louisiana ..... W. C. Pierce 561
Retentive Toxicity of Field-Weathered Insecticide Residues to Entomophagous Insects Associated with Citrus Pests in California ..... Blair R. Bartlett 565
Effect of Insecticides on the Metabolism and Motility of Mammalian Spermatozoa ..... Stanley D. Beck 570
Corn Earworm Investigations in Florida ..... N. C. Hayslip, E. G. Kelsheimer, W. H. Thames, Jr. and J. W. Wilson 574
The Effect of Certain Microorganisms and Antibiotics on Stored-Grain Insects ..... Edward A. Steinhaus and C. Ritchie Bell 582
A Comparison of Aldrin, Dieldrin, Heptachlor, and DDT for Control of Plague Vectors on the California Ground Squirrel ..... Raymond E. Ryckman, Charles T. Ames and Chester C. Lindt 598
Ethylene Dibromide for Control of Black Hills Beetle ..... C. L. Massey, R. D. Chisholm and N. D. Wygant 601
Tobacco Hornworm Control with Organic Insecticides ..... Norman Allen, C. R. Hodge, A. R. Hopkins and J. D. Early 604
Weight Loss in Stored Wheat Caused by Insect Feeding .... Gailen D. White 609
Chemotherapeutic Use of Insecticides for Control of Bloodsucking Insects ..... A. W. Lindquist, A. R. Roth, Robert A. Hoffman and W. W. Yates 610
Control of Corn Earworm Attacking Sweet Corn in California ..... O. G. Bacon, L. D. Anderson and H. T. Reynolds 614
Action of Some Aliphatic Thiocyanates Against DDT-Resistant Strains of the House Fly ..... C. Gustafson, Jr., T. Lies and T. Wagner-Jauregg 620
Determination of a Physiological Saline Solution for *Aedes aegypti* (L.) ..... Richard Oliver Hayes 624
Laboratory Culture of the Pink Bollworm on Chemically Defined Media ..... Herman F. Beckman, Sara M. Bruckart and Raymond Reiser 627
Comparative Effectiveness of the Ethyl and Methyl Homologs of Nine Phosphorous Compounds Against Four Cotton Pests ..... E. E. Ivy, C. F. Rainwater, A. L. Scales and L. J. Gorzycki 630
Field Tests with Sprays for the Control of Thrips and the Cotton Fleahopper .. C. R. Parencia, Jr. and C. B. Cowan, Jr. 633
Effectiveness of Lindane Vaporizers ..... R. A. Fulton, W. N. Sullivan and G. F. Mangan 639
Effect of Different Treatment Schedules for Control of Cotton Insects ..... R. L. Hanna and W. J. Mistric, Jr. 641
Performance of Malathon for Control of the Pea Aphid ..... L. P. Ditman, Amihud Kramer and A. O. Saulsbury, Jr. 645
Sterilization of Screw-Worm Flies with X-Rays and Gamma-Rays ..... R. C. Bushland and D. E. Hopkins 648
Some Effects of Storage at Different Temperatures on the Lipids of the American Roach and on the Resistance of This Insect to Heat ..... Sam C. Munson 657
Fall Migration of Aphids with Special Reference to the Green Peach Aphid ... J. H. Newton, M. A. Palmer and George M. List 667
Effectiveness Against Mosquitoes of General-Purpose Repellent Mixtures for Application to Clothing ..... Carroll N. Smith and I. H. Gilbert 671
Field Compatibility of Aramite and Sulfur in California ..... F. A. Gunther, H. T. Reynolds, and L. R. Jeppson 674

SCIENTIFIC NOTES:

Maggots Attacking Michigan Onions ..... LELAND G. MERRILL, JR. AND RAY HUTSON 678
Some Natural Enemies of Horse Flies in New York ..... H. TASHIRO AND H. H. SCHWARDT 680
Notes on the Biology of *Tabanus giganteus* ..... H. TASHIRO AND H. H. SCHWARDT 681
Control of Corn Earworm and Rice Weevil in Dent Corn with DDT-Mineral Oil Emulsions ..... W. A. DOUGLAS AND C. E. SMITH 683
Tests of Insecticides for Control of Chestnut Weevil Larvae in the Soil ..... E. R. VAN LEEUWEN 684
Relation between Winter Temperatures, Boll Weevil Survival, Summer Rainfall, and Cotton Yields ..... R. C. GAINES 685
Further Evidence of Tuber Damage by the Western Potato Flea Beetle ..... H. R. MACCARTHY 688
Tests with Aerosols for Control of the Pea Aphid ..... TOM A. BRINDLEY AND RALPH SCHOPP 689
The Biology and Control of the Nantucket Pine Moth and the European Pine Shoot Moth. ..... L. A. STEARNS 690
A Method for Eradication of the Mite, *Myocoptes musculinus* from Laboratory Mice ..... RICHARD D. STONER AND WILLIAM M. HALE 692
Control of Insects and Spider Mites on Cotton in 1952 ..... M. T. YOUNG AND R. C. GAINES 693
A Rapid Method for Estimating Aerial Spray Deposits ..... J. M. DAVIS AND K. R. ELLIOTT 696
The Stabilization of Scabrin Oil Sprays ..... NORMAN MITLIN AND W. A. GERSDORFF 698
Toxicity of Vapors of Four Chlorinated Hydrocarbon Insecticides to Resistant House Flies. ..... H. G. WILSON, J. B. GAHAN AND W. C. MCDUFFIE 699
Sensitivity to DDT of Nerve Ganglia of Susceptible and Resistant House Flies ..... JOHN J. PRATT, JR. AND FRANK H. BABERS 700
The Toxicity of Aldrin, Dieldrin, and Toxaphene to Rabbits by Skin Absorption ..... BARBARA L. JOHNSTON AND W. G. EDEN 702
Swaine Jack-Pine Sawfly in Wisconsin ..... DANIEL M. BENJAMIN AND NORBERT B. UNDERWOOD 703
Peach Tree Borer Control ..... DIAL F. MARTIN 704
An Ecological Study of Three Species of Mites on American Linden ..... WALTER C. ATCHESON 705
Control of Green June Beetle Larvae in Alfalfa Fields with Parathion ..... C. B. DOMINICK 705
Maggot Therapy of Actinomycosis ..... ROBERT J. DICKE 706
Effect on the Oriental Fruit Moth of Materials Used for Plum Curculio Control ..... OLIVER I. SNAPP 707
Differential Tolerance to Parathion of Two *Typhlodromus* Predatory on Cyclamen Mite ..... C. B. HUFFAKER AND C. E. KENNETT 707
Insect Vectors of Oak Wilt Fungus ..... C. L. GRISWOLD AND R. B. NEISWANDER 708
Pea Aphid Injury in Alfalfa Seed Fields ..... HERMAN F. MENKE 709
The Effect of Cellulose Acetate Sheets on *Lasioderma serricorne* ..... J. B. SIMEONE 709
Vitula edmandsii as a Pest of Honeybee Combs ..... V. G. MILUM 710
Uropoda agitans, a Mite Pest in Commercial Fishworm Beds ..... PHILIP C. STONE AND GILBERT D. OGLES 711
An Aspirator Modified for Sampling Large Populations ..... S. S. RISTICH AND DAN LOCKARD 711
A Technique for Mass-Culture of the Six-Spotted Mite ..... GLENN L. FINNEY 712
Detached Leaf Culture in Mite Nutrition Studies ..... J. G. RODRIGUEZ 713
Fall Armyworm Control on Late Planted Sweet Corn ..... CHARLES H. BRETT 714
Disinsectization of Aircraft by Lindane Vapors from Filters in the Ventilating System ..... K. D. QUARTERMAN AND W. N. SULLIVAN 715
The Natural Control of the Alfalfa Looper in Central California ..... M. PUTTARUDRIAH 723

EDITORIALS:

Retirement of Dr. L. M. Peairs ..... C. E. PALM AND E. N. CORY 717
The Employer's View of Entomological Training Research and Development of Insecticides ..... HARRY F. DIETZ 717

OBITUARIES:

Neale Frederick Howard 721
Perry Kips Harrison 721
William Ernest Blauvelt 722
Philip Walter Berg 722

PROPOSED ADDITIONS TO THE COMMON NAME LIST 724

PROCEEDINGS:

North Central Branch, Eighth Annual Meeting, 1953 725
Southwestern Branch, First Annual Meeting, 1953 728
Cotton States Branch, Twenty-Sixth Annual Meeting, 1952 730
Cotton States Branch, Twenth-Seventh Annual Meeting, 1953 732
Georgia Entomological Society, Seventeenth Meeting, 1953 735

BOOK REVIEWS 719, 740

JOURNAL OF ECONOMIC ENTOMOLOGY
ENTOMOLOGICAL SOCIETY OF AMERICA
Formerly Official Organ American Association of Economic Entomologists

Vol. 46 August, 1953 No. 4

Predatism by the Adult Hymenopterous Parasite and Its Role in Biological Control[1]

STANLEY E. FLANDERS, *Department of Biological Control, University of California Citrus Experiment Station, Riverside*

In the parasitic Hymenoptera parasitization is a function only of the immature stages, the adult being the stage of reproduction and of dissemination of the species. In many species, however, the adults are unable to reproduce to their full capacity without feeding on the body fluids of their hosts. This is not so much a matter of prolonging the life of the female as it is of supplying proteins needed for oogenesis (Doten 1911).

In this type of Hymenoptera the newly emerged female may or may not have ripe eggs in the ovary. According to DeBach (Moursi 1946), newly emerged females of *Mormoniella vitripennis*, a parasite of housefly puparia, contain ripe eggs but oviposit only after host-feeding. The present writer has observed that newly emerged females of *Aphytis* sp. parasitic on *Lepidosaphes beckii* ordinarily oviposit before host-feeding. However, if withheld from their host for a week at 80° F., the *Aphytis* females oviposit only after host-feeding. Newly emerged females of *Metaphycus helvolus* parasitic on *Saissetia* spp. do not contain ripe eggs, yet oviposition often occurs before host-feeding.

Host-feeding by the female indicates that oogenesis is about to begin or is already under way. The cessation of host-feeding in the presence of hosts indicates that oogenesis has ceased. This was demonstrated by the writer (Flanders 1935) with alfalfa weevil parasites *Peridesmia phytonomi*, *Spintherus* sp., and *Dibrachoides* sp. In the newly emerged female of *Peridesmia phytonomi*, host-feeding does not begin until the first oocyte equals in size the body of nurse cells attached to it.

If *Metaphycus helvolus* is withheld from its host for 3 weeks at 80° F., oogenesis ceases from lack of protein. When placed with its host, the female immediately starts feeding upon it, and three days later begins to oviposit. Dissection of the species shows that when the number of fully formed ripe eggs within a female is four or less, host-feeding precedes oviposition (Flanders 1942b). The host-feeding female alternately deposits eggs on or in the host and sucks up the host fluids through ovipositor punctures in the host's derm, the behavior of the female when using the ovipositor for obtaining food being quite distinct from her behavior when using it for egg deposition (Flanders 1942b).

It is significant that the habit of using the ovipositor as a trophic mechanism is usually, if not always, associated with the habit of using it to multilate the viscera of the host (Flanders 1951a). Hosts destroyed by mutilation are generally smaller than those suitable for receiving parasitic eggs. The unmated female of *Coccophagus ochraceus* How. does not host-feed, yet prior to depositing an egg under a host she apparently mutilates its viscera. The mutilation habit may have been the first step in the evolutionary development of the habit of host-feeding by the parasite adult, since it is usually a prerequisite for such feeding. Mutilation is not limited to the host species itself but extends to any hymenopterous parasite inhabiting the host.

Host-feeding and host mutilation on the part of the female parasite constitute a form of predatism. Such predatism appears to be limited to species of Hymenoptera having eggs considerably greater in diameter than the ovipositor through

[1] Paper No. 761, University of California Citrus Experiment Station Riverside, California.

which they pass, species which oviposit either in or adjacent to their hosts, and in which ovigenesis and ovisorption are synchronous processes (Flanders 1950). Predatism by hymenopterous adults is unknown in species which store their eggs in the oviducts, which require immersion of the egg in the body fluids of the host in order to complete embryonic development, and in which males and females differ in their host relations.

It is noteworthy that in 18 species of mealybug parasites (aphelinids, encyrtids, platygasterids) propagated by the writer, predatism has never been observed. It is significant that a number of these mealybug parasites are very successful in giving commercial control to their hosts.

In species of the chalcidoid genus *Metaphycus* parasitic on soft-scale insects, host-feeding occurs in varying degrees, being highly developed in *M. helvolus* (Comp.) and absent in *M. stanleyi* Comp. Nevertheless, the writer has observed that in the reduction of black scale infestations in the field *M. stanleyi* may be as effective as *M. helvolus*. Host-feeding apparently is not so well developed in *M. luteolus* (Timb.) as in *M. helvolus*, yet the former is more effective in holding its host species (*Coccus hesperidum* L.) at low densities.

With parasites of hosts that produce a honeydew attractive to ants, the habit of host-feeding by the female adult parasites is a distinct handicap to their reproduction, since the activity of the ants in gathering the honeydew interferes with such feeding and thus hinders optimum oogenesis (Flanders 1951b). The process of host-feeding requires a longer time than oviposition; consequently, a species that host-feeds suffers more from ant activity.

EFFECT OF PREDATISM ON THE HOST POPULATION.—It has been assumed (DeBach 1943; Flanders 1941, 1942a; Johnston 1915) that predatism on the part of the adult hymenopterous parasites, is always beneficial from the standpoint of biological control. Such an assumption may be unwarranted, however, since the beneficial results appear to be limited to the reduction of host population, not to the maintenance of the parasite at low densities.

Theoretically, a host population under control by a parasitic species characterized by host-feeding adults would exhibit oscillations of greater amplitude than it would under control by a species not so characterized. However, a newly introduced predatory parasite may bring a pest population under control long before it reduces the pest population to a density at which host-feeding inhibits reproduction of the parasite. Host-feeding would not be detrimental to biological control if the population oscillations occur below the economic zero.

It is by the destruction of host individuals in excess of the average seasonal population that the effective parasite maintains its host population at a more or less uniform level. The maintenance of the host population at a noneconomic level is an effect of the high searching capacity of the parasite, enabling it to exist at a relatively low host density (Flanders 1947). As pointed out by Smith (1937), this capacity results from two peculiarities of insect parasites: (1) the limitation of development to a single host individual, and (2) the discovery of the individual host by the gravid female.

It can logically be assumed that a greater number of hosts per individual parasite would be needed to maintain an effective parasite population when its oviposition and power of search are dependent in part on host-feeding by the adult than would be needed if oviposition and power of search were not so dependent. It is self-evident that, lacking any counter acting attribute or circumstances, the species of natural enemy that is most effective in holding its host in check is one that requires, for individual development, the fewest hosts.

Since the development of each progeny begins within the mother, the hosts consumed by the mother in order to mature her eggs should be charged to the efficiency of her offspring: the greater the proportion of hosts thus consumed by a population, the more inefficient is the average individual parasite in maintaining a low host population. Apparently, therefore, the species not characterized by host-feeding by adult females are most likely to be best qualified to maintain their host populations at the lowest densities.

Johnston (1915), in his study of the biology of the parasite *Tetrastichus asparagi*, stated that the host-feeding habit of the adult was evidently as useful in checking its host as was its parasitic develop-

ment, if not more so. Hartley (1922), however, observing that the young stages of the aphid *Myzus persicae* killed by the host-feeding of *Aphelinus semiflavus* also contained the eggs of the parasite, stated that such host-feeding defeats the "primary purpose" of parasitism. Field studies with the soft-scale parasite *Metaphycus helvolus* show that the proportion of parasite-containing hosts destroyed by predatism increases with the increase in number of the adult parasites, so that the production of adults tends to level off instead of increasing (DeBach 1943).

According to Nicholson (1933), if some parasites are destroyed during development, the "steady density" of the parasite species is unaltered, but that of the host species is increased and varies inversely as the fraction of parasites that escape destruction before maturity.

The value of parasite predatism is therefore affected by the relative abundance of host and parasite. Observations by DeBach (1943) and Flanders (1942b) show that the proportion of hosts destroyed by the predatism of a parasite tends to increase (1) with the decrease in density of susceptible hosts and (2) with the increase in proportion of hosts below the size suitable for oviposition. Obviously, this tendency is inimical to biological control, since it increases the number of hosts required to maintain a parasite population.

At low host population densities the initial host-feeding activities of the female *Metaphycus helvolus* may so deplete the host population that few individuals remain for later reproduction of the parasite. It seems obvious that this habit of *M. helvolus* would require a higher minimum host population for development than would be the case otherwise. Under laboratory conditions and in the presence of false hosts, the searching capacity of a parasite such as *Mormoniella* may be greatly reduced, the adult female destroying by host-feeding all the true hosts that she finds (Flanders 1944b) and thus failing to reproduce. This type of predatory destruction of the host population thus tends to reduce the controlling capacity of the parasite population, hosts being destroyed that would have served to increase its searching capacity.

At low host populations it is therefore more effective to have the mortality the result of parasitization than of predatism. Under such conditions the protein requirements of the parasite are at a minimum, the eggs produced by a parasite, but not deposited, being absorbed, and the egg material used to prolong life (Flanders 1950).

If host-feeding per se is detrimental at low host densities, the adverse effects may be counteracted by factors that increase the searching capacity of the species (Flanders 1947). In *Metaphycus helvolus*, for example, the possible detrimental effect of host-feeding may be counteracted by high voltinism (high number of parasite generations per host generation) or by the capacity of the female to undergo phasic castration in the prolonged absence of hosts.

The relative importance of host-feeding by the adult parasite, and of parasitization, in the reduction of a host population cannot be satisfactorily demonstrated, since it is impossible to evaluate these activities separately. DeBach (1943) found that parasitization of black scale by *Metaphycus helvolus* in the field constituted 25 per cent of the parasite-caused mortality. It has also been observed that when an infestation of yellow scale, *Aonidiella citrina* (Coq.), in the field has been reduced by the action of *Comperiella*, only 25 per cent of the mortality is an effect of parasitization (Flanders 1945). The assumption that an equally good reduction would not have been attained in time by parasitism alone has no basis in fact, however, since *Comperiella bifasciata* and *Metaphycus helvolus* may deposit eggs prior to any host-feeding (Flanders 1944a, 1942b).

The host-feeding habit of adult parasites appears, nevertheless, to be of value in the reduction of heavy infestations. It would also be of value if populations of the species were utilized to reduce the host population by periodic inundative releases, which eliminate from consideration the continuation of parasite reproduction in the field.

SUMMARY.—The continuous suppression of economic pest populations by hymenopterous parasites is an effect of the reproductive characteristics of the latter. With some species and under certain conditions, predatism by the adult parasite may interfere with reproduction. Such a habit tends to increase the ampli-

tude of population oscillations of host and parasite, and to increase the rate at which the parasite reduces high host densities. With pest populations that cause economic damage at relatively low densities, there is good reason to assume that predatism by the adult parasite is detrimental.

LITERATURE CITED

DeBach, Paul. 1943. The importance of host-feeding by adult parasites in the reduction of host populations. JOUR. ECON. ENT. **36**(5): 647–58.

Doten, Samuel B. 1911. Concerning the relation of food to reproductive activity and longevity in certain hymenopterous parasites. Nevada Agr. Expt. Sta. Tech. Bul. **78:** 7–30.

Flanders, S. E. 1935. An apparent correlation between the feeding habits of certain pteromalids and the condition of their ovarian follicles (Pteromalidae, Hymenoptera). Ann. Ent. Soc. Amer. **28**(4): 438–44.

Flanders, S. E. 1941. Peculiar habits of beneficial insects. Calif. Citrog. **26**(10): 285, 306.

Flanders, S. E. 1942a. Oösorption and ovulation in relation to oviposition in the parasitic Hymenoptera. Ann. Ent. Soc. Amer. **35**(3): 251–66.

Flanders, S. E. 1942b. *Metaphycus helvolus*, an encyrtid parasite of the black scale. JOUR. ECON. ENT. **35**(5): 690–8.

Flanders, S. E. 1944a. Observations on *Comperiella bifasciata*, an endoparasite of diaspine coccids. Ann. Ent. Soc. Amer. **37**(3): 365–71.

Flanders, S. E. 1944b. Olfactory responses of parasitic Hymenoptera in relation to their mass production. JOUR. ECON. ENT. **37**(5): 711–2.

Flanders, S. E. 1945. Coincident infestations of *Aonidiella citrina* and *Coccus hesperidum*, a result of ant activity. JOUR. ECON. ENT. **38**(6): 711–2.

Flanders, S. E. 1947. Elements of host discovery exemplified by parasitic Hymenoptera. Ecology **28**(3): 299–309.

Flanders, S. E. 1950. Regulation of ovulation and egg disposal in the parasitic Hymenoptera. Canad. Ent. **82:** 134–40.

Flanders, S. E. 1951a. Mass culture of California red scale and its golden chalcid parasite. Hilgardia **21**(1): 1–42.

Flanders, S. E. 1951b. The role of the ant in the biological control of homopterous insects. Canad. Ent. **83**(4) 93–8.

Hartley, E. A. 1922. Some bionomics of *Aphelinus semiflavus* (Howard), chalcid parasite of aphids. Ohio Jour. Sci. **22**(8): 209–36.

Johnston, F. A. 1915. Asparagus-beetle egg parasite. Jour. Agr. Res. **4:** 303–14.

Moursi, A. A. 1946. The effect of temperature on development and reproduction of *Mormoniella vitripennis* (Walker). Soc. Fouad I Univ. Fac. Sci. Bul. Entom. **30:** 39–61.

Nicholson, A. J. 1933. The balance of animal populations. Jour. Animal Ecol. **2**(Sup.): 132–78.

Smith, Harry S. 1937. Review (Sweetman, Harvey L. The biological control of insects. Comstock Pub. Co., Inc., Ithaca, New York. 1936) JOUR. ECON. ENT. **30**(1): 218–20

DR. ROGER SMITH RETIRES

Dr. Roger C. Smith retired as Head of the Department of Entomology at Kansas State College on June 30, 1953, having reached the age of mandatory retirement for administrators. He will remain on as a full time research member of the Department. Dr. Herbert Knutson, formerly Head of the Department at the University of Rhode Island and formerly Administrator of the Division of Entomology and Plant Industry of the Rhode Island Department of Agriculture & Conservation, has been named his successor.

The Effects of Some Soil Characteristics on DDT Phytotoxicity

RICHARD THURSTON, *Department of Entomology and Botany, University of Kentucky, Lexington*

The chemical stability and insolubility in water of DDT has raised the problem of phytotoxic residue accumulations of DDT in soils where agricultural crops have been sprayed or dusted with this insecticide for a number of years. Reports by several investigators indicate that the problem of DDT residues in soil may be as important, if not more so, than the problem of arsenical residues in soil has been in such regions as South Carolina, West Virginia, and the apple growing areas of the Pacific Northwest.

Differences in the phytotoxicity of DDT when applied to different soil types have been reported. Appleman & Sears (1946) found that plants grown in soil treated with DDT were not so stunted as those grown in sand treated with DDT at the same rates. Goldsworthy (1949) found no consistent relationship between the phytotoxicity of DDT incorporated in various soil types and the soil texture. Foster (1951) reported that DDT in a New Jersey muck soil was much less toxic to plants than similar concentrations in mineral soils. Another muck soil, containing a larger amount of silt and less organic matter, was intermediate between the New Jersey muck soil and the mineral soils in the phytotoxicity of the DDT applications. Investigations by the author to study the effect of various soil characteristics on the phytotoxicity of DDT were carried on at the New Jersey Agricultural Experiment Station from 1950 to 1952 and continued at the Kentucky Agricultural Experiment Station.

PLANT RESPONSE TO DDT IN DIFFERENT SOIL TYPES.—Seven New Jersey soils with large variations in texture and organic matter content were used in these experiments. Open ended 55-gallon drums sunk 28 inches in the ground were used as containers. The C horizon, a coarse sandy loam of the Sassafras series, was that of the field in which the drums were sunk. The A and B horizons of each soil were kept separate and placed in the cylinders in the position that they were taken from the various fields. Each horizon had a depth of approximately nine inches after settling. For each soil type there were three replications for the treatment; an untreated check, purified DDT at the rate of 200 pounds an acre, and technical DDT at the rate of 200 pounds an acre. The DDT dusts[1] were scattered on the soil surface and thoroughly mixed with the top 4 inches of soil on July 7, 1950. The pH values of the soils during the course of the experiments are given in Table 1. The pH values were made more alkaline by the addition of varying amounts of dolomitic limestone.

Three harvestings of DDT susceptible plant varieties were made. The first planting, Stringless Green Pod bush beans, showed rather erratic results and there was evidence of only slight phytotoxicity from the DDT in most of the soils. The lack of toxicity may have been the result of poor mixing of the DDT with the soil or of not mixing the DDT deeply enough in the soil.

Table 1.—The pH values of the seven soil series in soil cylinders during the period of experimentation.

Soil Series	pH August 28, 1950	pH May 24, 1951	pH October 7, 1951
Lakewood	4.4	6.1	6.6
Sassafras	5.6	6.6	6.4
Nixon	5.7	6.4	6.3
Norton	5.1	6.1	6.5
Frenau	4.7	5.9	6.4
Peat	5.0	5.6	6.2
Neshanic	6.2	6.6	6.6

Lime treatments—October 3, 1950 and June 6, 1951.

Abruzzi rye planted in the fall of 1950 and harvested the following spring was extremely stunted by both technical and purified DDT in all the soils except the peat (Table 2). Many of the rye plants in all of the DDT treated soils except the peat turned purple when they reached a height of five to six inches. A considerable number of these purpled plants died, re-

[1] Provided by Geigy Company, Inc.

Table 2.—Effect on Abruzzi rye of technical and purified DDT incorporated in seven New Jersey soils at the rate of 200 pounds per acre on July 7, 1950. Rye was grown from October 12, 1950 to April 22, 1951.

Soil Type	DDT Treatment	Green Wt. in Gms.	Per Cent Difference from Check	Dry Wt. in Gms.	Per Cent Difference from Check
Lakewood sand	None	596		132	
	Purified	255	−57	50	−62
	Technical	304	−49	63	−52
Sassafras sandy loam	None	1281		262	
	Purified	870	−32	188	−29
	Technical	654	−49	145	−45
Nixon sandy loam	None	2063		380	
	Purified	1180	−43	258	−32
	Technical	1042	−50	212	−44
Norton loam	None	1185		254	
	Purified	570	−52	113	−56
	Technical	510	−57	109	−57
Frenau silt loam	None	830		154	
	Purified	575	−31	112	−27
	Technical	580	−30	103	−33
Peat	None	1265		241	
	Purified	1045	−18	206	−14
	Technical	1190	− 6	226	− 6
Neshanic silt loam	None	950		185	
	Purified	415	−56	73	−61
	Technical	270	−72	44	−76

sulting in poor stands, but the effect of the DDT was the result of stunting of plant growth as well as poor stands. The purpling of the rye leaves occurred only in the early stages of growth; after the plants had reached a height of about 10 inches, those plants that had not died completely lost this discolorization.

Black Valentine beans grown during the summer of 1951 showed stunting effects from the DDT similar to those shown by the rye, except that the bean plants showed no off-color (Table 3). Bean plants growing in the untreated Lakewood sand showed much better growth than those growing in the DDT treated Lakewood sand at first, but growth was poor in this soil in all treatments because of faulty fertilization.

No relationship between DDT phytotoxicity and soil texture could be seen in these tests. The amount of organic matter, however, did seem to be an important factor in reducing the phytotoxicity of the DDT since neither purified nor technical DDT was highly toxic to either the rye or the beans when it was incorporated into the peat soil. The purified DDT was found in most cases to be less phytotoxic than technical DDT.

Adsorption of DDT in Nutrient Solution Culture Experiments.—Because of the numerous chemical and physical factors present in soils, the use of a less complex and more easily controllable system than soil was thought to be preferable for further studies. A nutrient solution culture system was chosen because it has few unknown chemical and physical factors and it can be easily handled and manipulated. Also the development of the root system can be observed easily throughout the period of experimentation.

A Shive & Robbins nutrient solution[1] was used in all tests. Aeration was provided by a Thiberg or a White Mist aerator. Quart or 2 quart jars were used in all the experiments. Except in tests to determine the effect of DDT on chemical constituents of the foliage where solutions and treatments were renewed every other day, the solutions were not renewed but distilled water was added when neces-

[1] New Jersey Agr. Expt. Sta. Bul. 636, p. 16.

Table 3.—Effect on Black Valentine beans of technical and purified DDT incorporated in seven New Jersey soils at the rate of 200 pounds per acre on July 7, 1950. Beans were grown from June 11 to August 15, 1951.

Soil Type	DDT Treatment	Plant Wt. Minus Pods		Pod Weight	
		Gms.	Per Cent Difference from Check	Gms.	Per Cent Difference from Check
Lake wood sand	None	985		541	
	Purified	1160	+18	434	−19
	Technical	1140	+16	486	−10
Sassafras sandy loam	None	1940		1659	
	Purified	1760	− 9	1267	−24
	Technical	1445	−26	707	−59
Nixon sandy loam	None	2230		1800	
	Purified	1990	−11	1505	−16
	Technical	1735	−22	1061	−41
Norton loam	None	1730		1427	
	Purified	1445	−17	805	−43
	Technical	825	−52	433	−69
Frenau silt loam	None	2135		1786	
	Purified	1920	−10	1318	−26
	Technical	1790	−16	1321	−25
Peat	None	2230		1469	
	Purified	2050	− 8	1567	+ 7
	Technical	2005	−10	1481	+ 1
Neshanic silt loam	None	1915		1734	
	Purified	1560	−19	781	−55
	Technical	835	−54	371	−79

sary to make up the required volume of liquid. A 50 per cent purified or technical DDT[1] wettable powder was used to make up stock suspensions of the insecticide. Black Valentine snap beans were chosen as the indicator plant because of their rapidity of growth and their susceptibility to DDT poisoning. The seeds were germinated in washed sand and the seedlings transferred to the nutrient solution as soon as the primary leaves had unfolded. Treatments were added to the solutions two days after the seedlings had been transferred. The material to be tested, such as wood carbon or an ion exchange resin, was placed in 50 milliliters of distilled water in a beaker, or a small paper cup, and then the DDT was added. These suspensions were left for 4 hours with frequent stirring to provide intimate contact of the test material and the DDT, and then they were poured into the jars of nutrient solution. Because the material or materials responsible for the phytotoxicity of DDT are not definitely known, the term DDT will be used for the toxic ingredients.

Preliminary tests showed that the purified DDT at concentrations as low as one part per 10 million was toxic to the bean seedlings. At this level and at one part per million, DDT curtailed lateral root development and there was a tendency to get many thick unbranched roots. At 10 parts per million, there was an almost complete cessation of root development so this concentration of DDT was used in all subsequent experiments (Table 4). While root development was almost immediately arrested upon addition of this level of DDT, top growth did not begin to become stunted until a week or 10 days later. For this reason the length, the appearance and the weight of the root system were used as criteria to determine the effect of various materials in detoxifying or absorbing the DDT. The inert ingredients of the DDT wettable powder

[1] Provided by Geigy Company, Inc.

Table 4.—Effect of technical DDT on Black Valentine beans grown in nutrient solutions for 21 days after treatment.

Treatment	Green Wt. in Gms.	Per Cent Difference from Check	Dry Wt. in Gms.	Per Cent Difference from Check	Dry Wt. of Roots in Gms.	Per Cent Difference from Check
Check	70.0		8.4		1.581	
DDT 1 pp 10 m	66.5	− 5	7.1	−15	1.392	−12
DDT 1 ppm	57.0	−19	5.1	−39	1.195	−24
DDT 10 ppm	39.0	−44	4.5	−46	0.714	−55

were found to be non-toxic to the plants.

Four ion exchange resins[3]: a cation exchange resin, IR 120; two strong-base anion exchange resins, IRA 400 (chloride form) and XE 98; and a weak-base anion exchange resin, IR4B, were tested. At 3000 ppm all the anion exchange resins decreased the toxicity of the DDT but the cation exchange resin was not effective (Table 5). The strong-base anion exchange resins, XE 98 and IRA 400, were much more effective than the weak-base anion exchange resin in reducing DDT phytotoxicity. XE 98 appeared to be slightly more effective than IRA 400. These data indicate that DDT may be exchanged as an anion or may be decomposed by the anion exchange resins. If the exchange complex is the functioning mechanism then from the greater effect of IRA 400 and XE 98, compared to 1R4B, it would be assumed that the phytotoxic material is being exchanged as a weak acid.

If the adsorption of DDT is similar to that of the phosphate and arsenate ions, we can predict some of the relationships between the phytotoxicity of DDT incorporated in soil and the soil characteristics. Phosphate adsorption is decreased by an increase in the pH value of the solution. Foster (1951) reported that the liming of some soils increased the phytotoxicity of DDT but the author could not establish this point in small plot tests or in greenhouse tests. The phosphate ion is adsorbed by the clay fraction and is adsorbed in greater degree where the soil has a low cation—anion exchange capacity ratio. In general, this condition correlates with a low Si O_2-R_2O_3 ratio. Therefore, the amount and type of clay should have an important influence on the adsorption of DDT by soils. The use of kaolinitic and montmorillonitic clays to adsorb DDT in nutrient solution culture experiments have given inconsistent results so this work is being continued. In general, however, if any reduction of DDT phytotoxicity has occurred it has been slight when compared to the effect of ion exchange resins or activated carbons. The

[3] Provided by Rohm and Haas Co.

Table 5.—Effect of ion exchange resins on the toxicity of purified DDT to Black Valentine bean seedlings grown in nutrient solutions.

Treatment	Average Root Length in Inches	Per Cent Difference from Check	Root Appearance
Check	11.50		Excellent
DDT 10 ppm	6.00	−48	Poor
IR-120 1000 ppm and DDT 10 ppm	6.50	−43	Poor
IR-120 3000 ppm and DDT 10 ppm	6.75	−41	Poor
IR-4B 1000 ppm and DDT 10 ppm	5.50	−52	Poor
IR-4B 3000 ppm and DDT 10 ppm	7.25	−37	Fair
IRA-400 1000 ppm and DDT 10 ppm	8.75	−24	Fair
IRA-400 3000 ppm and DDT 10 ppm	9.50	−17	Good
Check	13.25		Excellent
DDT 10 ppm	4.75	−64	Poor
IRA-400 2000 ppm and DDT 10 ppm	6.25	−53	Fair
XE-98 2000 ppm and DDT 10 ppm	8.00	−39	Good
IRA-400 3000 ppm and DDT 10 ppm	11.25	−15	Excellent
XE-98 3000 ppm and DDT 10 ppm	12.25	− 7	Excellent

Table 6.—Composite table of the effect of two activated carbons on the toxicity of technical DDT treatments to Black Valentine beans grown in nutrient solutions.

TREATMENT	AVERAGE ROOT LENGTH IN INCHES	PER CENT DIFFERENCE FROM CHECK	ROOT APPEARANCE
DDT 10 ppm and wood carbon 500 ppm	12.0	+ 4	Excellent
DDT 10 ppm	4.5	−61	Poor
DDT 10 ppm and wood carbon 1000 ppm	12	0	Excellent
DDT 10 ppm and bone carbon 1000 ppm	5	−58	Poor
DDT 10 ppm	5	−58	Poor
DDT 10 ppm and wood carbon 1000 ppm	16.5	+14	Excellent
DDT 10 ppm and bone carbon 4000 ppm	16.5	+14	Excellent
DDT 10 ppm	8.5	−47	Poor

influence of clay on the phytotoxicity of DDT was not observed with the seven soils in the field tests although there was a high positive correlation between the clay content and the phosphate fixing capacity of the soil. However, DDT may be very weakly attached to the clay structure and the presence of other anions such as the phosphate or sulfate ion may displace the DDT, just as the arsentate ion is displaced by the phosphate ion. This might explain why some workers have found that fertilization increased the phytotoxicity of DDT. Organic matter and organic soils have practically no anion exchange capacity although there is an insignificant positive adsorption under acid conditions changing to negative adsorption under alkaline conditions. The peat soil used by the author was found to have practically no phosphate fixing capacity. Thus the detoxification of DDT by organic soils would not seem to be explainable by a theory of anion exchange unless the exchange of certain organic anions is different than the exchange of inorganic anions. The tying-up of DDT by organic matter may be a purely physical phenomenon such as is probably true with the activated carbons.

Two activated carbons, Aquar nuchar B and a bone carbon, proved to be very effective in reducing the phytotoxicity of DDT. The activated bone carbon was less effective than the activated wood carbon when tested on ar equal weight basis but was nearly equal in effectiveness when tested on a similar volume basis (Table 6). At equal volumes the bone carbon weighed four times as much as the wood carbon.

The action of the activated carbons on DDT could be attributed to the purely physical factors involved, such as entrapment or the mutual physical attraction of the DDT and carbon particles. Kunin & Myers (1947) state that charcoal acts similarly to the amine type exchange resins. However Steenberg (1944), discussing adsorption and exchange of ions on activated carbons, states that the adsorption of gases and solutes is not exclusively a chemical interaction between the charcoal and the substances adsorbed and that "the generally accepted conception of adsorption on charcoal of gases and organic non-electrolytes from solutions is founded on a theory of physical surface action (van der Waal's forces), and not on chemical reactions. The adsorption by the carbons of the phytotoxic material in the DDT preparations from this would be deduced to be a physical reaction.

Because of the possibility of the purpling of the Abruzzi rye plants in the soil tests being due to a deficiency of phosphorus, Black Valentine bean seedlings were grown in nutrient solutions containing DDT for analyses of plant nutrients. The nutrient solutions and treatments were replaced every other day. Analyses of the green foliage, carried out according to the procedures of Emmert (1934) and Morgan (1941), showed that the soluble phosphorus was much lower in the plants treated with DDT than in the untreated plants (Table 7) even though no deficiency symptoms were visible. Recent experiments with Kentucky-16 burley tobacco have given symptoms resembling phosphorus deficiency when the tobacco seedlings were grown in nutrient solutions containing chlordane at five parts per million, but

Table 7.—Analyses of Black Valentine bean foliage for uptake of elements by plants treated with purified DDT in nutrient solution cultures.

Treatment	Parts per Million					
	P	Cl	Ca	Mg	K	Na
Untreated check	510	165	375	130	1080	150
Acetone 500 ppm	500	205	500	180	1000	285
DDT 10 ppm and acetone 500 ppm	225	175	325	135	1100	280

no plant analyses have been made. Jakob (1950)[1] in an unpublished thesis reported in experiments similar to those of the author that phosphorus and nitrate nitrogen in snap beans were reduced by the addition of lindane to the nutrient solutions.

Summary. In field tests using soil cylinders, snap beans and Abruzzi rye were severely stunted by both purified and technical DDT incorporated at the rate of 200 pounds per acre in six New Jersey mineral soils of varying texture. Purified and technical DDT incorporated in a peat soil at the same rate were much less phytotoxic than when incorporated in the mineral soils. No relationship between the texture of the mineral soils and the amount of DDT phytotoxicity was apparent. Although in some cases the phytotoxicity caused by purified DDT was less than that caused by technical DDT, the differences in the injury caused by the two materials were slight.

Greenhouse experiments in which DDT was added to nutrient solution cultures showed that consistent reductions in the root growth of Black Valentine bean seedlings could be obtained by the end of ten days. Purified DDT at the rate of 10 parts per million almost completely stopped root growth. At lower rates the development of lateral rootlets was curtailed and many thick, unbranched roots were produced. Analyses of bean foliage showed that the soluble phosphorus in plants treated with purified DDT was about half that found in the untreated plants.

Two strong-base anion exchange resins, IRA 400 and XE 98, when added to nutrient solutions containing DDT were found to reduce DDT phytotoxicity; a weak base anion exchange resin, IR4B, was markedly less effective in reducing phytotoxicity; and a cation exchange resin, IR 120, had no effect on the phytotoxicity of DDT. Wood and bone activated carbons were very effective in adsorbing DDT and preventing phytotoxicity.

[1] Jakob, W. 1952. Studies on phytotoxic properties of benzene hexachloride. Unpublished master's thesis. Rutgers University.

Literature Cited

Appleman, M. C. and O. H. Sears. 1946. Effects of DDT on nodulation of legumes. Jour. Amer. Soc. Agronomy **38:** 545–56.

Emmert, E. M. 1934. Tests for phosphate, nitrate and soluble nitrogen in conducting tissue of tomato and lettuce plants as indicators of availability and yield. Ky. Agr. Expt. Sta. Circ. **43:** 25–40.

Foster, A. C. 1951. Some plant responses to certain insecticides in the soil. U.S.D.A. Circ. **862.**

Goldsworthy, M. C. 1949. Effect of technical DDT incorporated in quartz sand and soils on the growth of peach trees. Plant Dis. Reptr. **32:** 437–41.

Kunin, R. and R. J. Myers. 1947. The anion exchange equilibria in an anion exchange resin. Jour. Amer. Chem. Soc. **69:** 2874—8.

Morgan, M. F. 1941. Chemical soil diagnosis by the universal soil testing system. Conn. Agr. Expt. Sta. Bul. **450:** 579–628.

Shive, J. W. and W. R. Robbins. 1948. Methods of growing plants in solution and sand cultures. N. J. Agr. Expt. Sta. Bul. **636.**

Steenberg, Börje. 1944. Adsorption and exchange of ions on activated charcoal. Uppsala, Almqvist and Wiksells boktryckeri aktiebolag.

A Survey of the Mediterranean Region for the Beet Leafhopper

NORMAN W. FRAZIER, *University of California, Berkeley*

According to Ball (1917) the sugar beet industry in western United States had its inception at Alvarado, California, in 1870, and by 1900 sugar factories were operating in California, Colorado, Nebraska, New Mexico, Washington, Oregon and Utah. In 1899 a disease appeared in the California plantings so serious as to threaten the new industry. It was called "California Blight" or "Western Blight" and during 1899 and 1900 was found in every western beet growing area. The disease was later known as "curly-leaf" and finally as at present, "curly-top". It has since been present continuously in the western sugar beet regions, fluctuating widely in prevalence over the years. In California, peak years of disease were experienced in 1900, 1905, 1914 1919, 1925 and 1950. In addition to beets, other crops that may suffer important losses in California include tomatoes, melons, spinach, flax, and beans.

The curly-top disease is caused by a virus which is carried by the beet leafhopper, *Circulifer tenellus* (Baker). It is the only species of insect known to be capable of spreading the virus. The beet leafhopper was first recorded on sugar beets by Gillette & Baker (1895) who found it at Grand Junction, Colorado. Because of the insect's association with sugar beets and especially the "curly-leaf" disease, it was named the beet leafhopper by Ball (1907b). In North America the species has been found in most of the western states of this country and in British Columbia, Lower California and Mexico. In addition, it has more recently been found to exist in Florida and a number of islands of the West Indies.

The species was originally described by Baker (1896) as *Thamnotettix tenellus* and was referred to the genus *Eutettix* by Ball (1907a). It had long been recognized by specialists that *T. tenellus* did not properly belong in the genus *Eutettix*, and that there was an apparent absence from the New World of any species closely related to it. As a result of his studies of material from other faunal regions of the world in an effort to determine the correct generic position of the beet leafhopper, Oman (1936, 1948, 1949) found that *T. tenellus* was associated with a number of Old World species contained in the genus *Circulifer* and therefore should properly be referred to as *Circulifer tenellus*. He recognized 12 Old World species of *Circulifer* and gave their distribution as follows: the countries of southern Europe adjacent to the Mediterranean, the Balkan States, northern Africa, Yemen, Palestine, northern Arabia, the area around the Caspian Sea, the Punjab district of North India and the desert and arid regions of Asia from the Persian Gulf to the Northeast as far as the steppe of Balagansk in south central Siberia. The ecological similarity of the Old World areas to that occupied by the beet leafhopper in North America was pointed out.

Oman (1948) further determined that two species described from the old World, one from Palestine and the other from Sicily, were synonymous with the North American beet leafhopper and thereby established the presence in the Mediterranean region of *Circulifer tenellus*. This evidence strongly suggested that the beet leafhopper is not native to North America but rather that it is an introduced species the original home of which was somewhere in the Old World. It is of interest to note (Oman, 1949) that as early as 1926 some workers believed that the beet leafhopper was not a native North American species. As a result a search was made in Argentina (Severin & Henderson, 1928) for the beet leafhopper because of the interest in obtaining parasites from the presumed original home of the species.

Over the years, methods that have been used in California to combat curly-top losses have included the use of resistant crop varieties, alteration of time of planting, the use of insecticides directed against the leafhopper both on individual crop plantings and on its wild hosts in or near its breeding grounds, the elimination of Russian thistle infestations, and the maintenance of a population prediction service to warn growers of expected high levels of leafhoppers and disease.

Under the extraordinarily favorable conditions that prevailed in the overwintering and spring breeding areas of the beet leafhopper in California in 1949 and 1950 these methods did not suffice to prevent the increasingly serious losses experienced in those years, especially by growers of melons and fresh market tomatoes. In response to an appeal by growers the California State Legislature in 1950 allocated funds for an emergency aid program and also requested the College of Agriculture of the University of California to undertake a search for natural enemies of the beet leafhopper. The University of California subsequently initiated a research project relative to the biological control of the beet leafhopper under the direction of the Department of Biological Control.

As one of the initial steps in the project, and based upon the work of Oman, a preliminary survey was made of the Mediterranean region to locate populations of *Circulifer tenellus* and obtained as much basic information as possible regarding its Old World distribution, host plants and natural enemies. The overall objective of the survey was to lay a sound foundation for possible future work by a parasite specialist.

The present paper reports some of the results of this preliminary survey.

ITINERARY.—The trip was of nearly 7 months duration, from February 21 to September 15, 1951. Travel between main points was by plane. On the trip eastward examinations were made of the insect collections at the U. S. National Museum, the British Museum (Natural History), London, the National Museum of Natural History, Paris, the Spanish Institute of Entomology, Madrid, Spain and of the private collection of Dr. Henri Ribaut, Toulouse, France. It was desired to learn as much as possible concerning the genus *Circulifer* and to obtain collection records of all the representatives of the genus that were found. It was thought that such data would prove to value in determining the the areas in which field work might most profitably be accomplished.

After leaving Madrid the first field collecting was started in Algeria, April 1 to 14, and in the following sequence continued in Tunisia, April 15 to 21, Egypt, April 22 to May 12, Syria, May 13 to 17 Lebanon, May 18 to 23, Cyprus, May 24 to 31, Turkey, June 1 to 14, Greece, June 15 to 21, Italy, including Sardinia and Sicily, June 22 to July 23, Tripolitania, July 24 to 31, and ended in Spain, August 5 to 20.

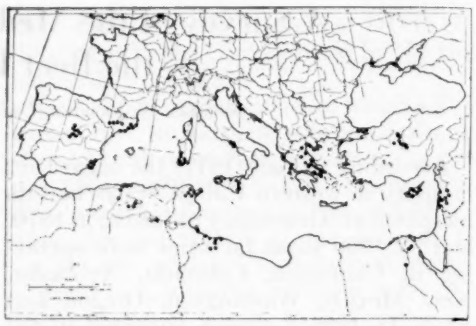


FIG. 1.—Outline map showing the Mediterranean areas searched for the presence of the beet leafhopper, *Circulifer tenellus* (Baker). The solid circles indicate the approximate localities where collections were made.

Based on Goode Base Map No. 129, Copyright 1939 by the University of Chicago. Used by permission of The University of Chicago Press.

PROCEDURE.—The itinerary was planned to allow the minimum of time estimated to be essential in each country to get to and adequately sample the areas which were thought the most likely to be habitats of *Circulifer tenellus*. It was not found possible to make intensive or detailed study of any population or accumulate life history data. It was likewise difficult to get reliable determinations of unknown host plant species.

Collecting was done with an insect sweep net and the leafhoppers were aspirated from the net, killed in a cyanide jar and preserved dry in pill boxes. A special effort was made to concentrate the field work in habitats that appeared ecologically suited to *Circulifer tenellus* if such habitats could be found in any given country. However, when opportunity was afforded collections were made in other habitats and on as many host plants as possible in an attempt to get a sample of the total leafhopper fauna. Not only *Circulifer* but all other leafhoppers swept were preserved.

RESULTS.—Approximately 30,000 specimens of Cicadellidae were collected and preserved during the trip. Of these about 7,500 represented species of the genus *Circulifer*.

The genus *Circulifer* was found to be common over all of the areas surveyed,

in some localities only in low populations, while in others in fair abundance. A number of described species were represented as well as several new species. The specimens collected during this survey have formed the basis of a study of the genus *Circulifer*, presently in progress,[1] in which the writer is collaborating. As a result of this study it has been determined that *Circulifer tenellus* was collected in Algeria, Tunisia, Tripolitania, Egypt and Spain.

The species associated in the genus *Circulifer* by Oman (1948) may be conveniently segregated into three groups: the *C. fenestratus* group, typically black or brownish leafhoppers which probably consitute a distinct and apparently monotypic genus (*Distomotettix*, Ribaut); the *C. haematoceps* group, characterized by having triangulate male plates; and the *C. tenellus* group, distinguished by having the male plates truncate at the apices.

Examples of the *Circulifer fenestratus* group were found in every country in which collections were made. With few exceptions they were found only as scattered individuals. On one occasion near Cagliari, Sardinia, a breeding spot was found where fair numbers of nymphs and adults were taken on an unidentified host. The most common host plant was *Scolymus hispanicus* L. (golden thistle). Other hosts included species of *Juniperus*, *Cistus*, *Rosmarinus*, *Micromeria* and *Prosopis*. Populations were ordinarily too small to determine the host plant from which they were swept.

Representatives of the *Circulifer haematoceps* group were also taken in every country. However, only a few were found in Egypt. In all countries excepting Egypt they were the dominant form of *Circulifer*. They were more commonly distributed, collected more often and usually in greater abundance, and were found on a greater variety of plant hosts than members of either the *C. fenestratus* or *C. tenellus* groups. Included among their more common host plants were numerous species of Cruciferae, Chenopodiaceae, Amaranthaceae and several species of *Cistus*. Other hosts, including some of importance, were *Thymus vulgaris* L. (common thyme), *Rosmarinus officinalis* L. (rosemary) and species of *Plantago*, *Artemesia*, *Portulaca*, *Euphorbia*, *Marrubium*, *Micromeria*, *Prosopis*, and *Erodium*.

Species of the *tenellus* group were collected only in Algeria, Tunisia, Tripolitania, Egypt, Turkey, Sardinia and Spain. Populations were not found in great abundance and the distribution of some of the forms appeared to be sharply limited by undetermined factors. Often a population would be found only in a small sampling area but not in surrounding or adjacent areas that appeared equally, or more, favorable. In several instances distribution appeared limited to a narrow zone bordering lake or sea shores. Specimens were usually collected in very moderate or small numbers. Known host plants included species of Cruciferae and *Alyssum*, *Chenopodium*, *Salsola*, *Cistus* and *Zygophyllum*. A number of collections yielded so few specimens that their host plants were only doubtfully determined. In general, the Cruciferae appeared to be the most important group of host plants.

Particular efforts were made in all countries to observe plantings of beets, tomatoes and other hosts of the curly-top virus, including wild beets and other wild plants, to determine if the curly-top virus were present in any country visited. Symptoms of curly-top were not positively identified on any plant.

In general the ecological characteristics of the genus *Circulifer*, and especially the *C. tenellus* group, as observed in the Mediterranean region, were very similar to those of the beet leafhopper in western North America in so far as habitat and host plants are concerned. However, the Mediterranean populations seemed to differ in three important respects: (1) In no area of the Mediterranean was sugar beet or wild beet a good host plant of *Circulifer* although good populations were occasionally found on weeds growing in and around sugar beet plantings. No *C. tenellus* group specimens were ever collected on beets. (2) Russian thistle, though not found abundantly was never observed to be more than a relatively mediocre host of any species of *Circulifer*. Only adults were found on this host. (3) Most *C. tenellus* group populations appeared to have a restricted distribution locally.

In all countries in which both *Circulifer tenellus* and *C. haematoceps* group species

[1] Dr. D. A. Young, Jr., Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, U.S.D.A., Washington, D. C.

were found, with the exception of Egypt, the latter were always the most abundant and evenly distributed although food plants, habitats and climate seemed to be equally as favorable for *tenellus* group leafhoppers. This was especially true in Spain where seemingly as great a diversity of *Circulifer* species, host plants and habitats was found as in all other sampled countries combined. It is possible that biological control factors might be at least a part of the explanation.

No particular effort was made to study the parasites or predators of *Circulifer*. However, it is known that parasites were not uncommon. A number of specimens were collected that were parasitized with undetermined species of internal and external parasites and egg parasites were recovered at Albany, California, from a shipment of host plant material from Tripolitania to the quarantine laboratory of the Department of Biological Control.

Of all of the areas surveyed, Spain seemed to be the most favorable in which further search might be conducted for parasites and predators for the reasons: (a) Spain appeared to be climatically and ecologically most similar to the areas of California infested by the beet leafhopper; (b) floral associations in Spain are similar to those in California with many identical species among *Circulifer* host plants; (c) a greater diversity of species and forms of *Circulifer* were encountered in Spain than in any other country; (d) parasitism was observed in both the *C. haematoceps* and *C. tenellus* group populations; (e) most areas of Spain are readily accessible and with few collecting difficulties; (f) Spain is so situated that, as a headquarters of operations, activities could easily be extended to cover any western Mediterranean area including North Africa.

SUMMARY.—As an initial step in a project to investigate the possibilities of biological control of the beet leafhopper, *Circulifer tenellus* (Baker) undertaken by the Department of Biological Control of the University of California, a survey for the beet leafhopper and its close relatives was conducted in the Mediterranean region.

Collections were made in Algeria, Tunisia, Tripolitania, Egypt, Syria, Lebanon, Cyprus, Turkey, Greece, Italy, Sardinia, Sicily, and Spain. Nearly 30,000 specimens of Cicadellids were collected, of which about 7,500 were *Circulifer*.

Among the *Circulifer*, the beet leafhopper, C. *tenellus*, was taken in Algeria, Tunisia, Tripolitania, Egypt, and Spain. Some observations on distribution and host plants of the *Circulifer* are given.

Spain appeared to be the most favorable area in which to search for parasites and predators of the beet leafhopper.

ACKNOWLEDGEMENT.—The author is sincerely grateful for the kind assistance received from numerous people among whom were Dr. J. Carayon, of the Department of Colonial Agricultural Entomology in Paris; Dr. W. E. China, of the British Museum of Natural History in London; Dr. Z. Düzgünes, of the Plant Protection Institute in Ankara; Dr. H. L. Parker, of the European Parasite Laboratory of the U. S. Department of Agriculture in Paris; Prof. R. Pasquier, of the Agricultural Institute of Algeria in Algiers; Dr. E. Séguy, of the Natural History Museum of Paris; and Dr. D. A. Young, Jr., of the Division of Insect Detection and Identification of the U. S. Department of Agriculture in Washington, D. C.

LITERATURE CITED

Baker, C. F. 1896. New homoptera received from the New Mexico Agricultural Experiment Station. II. Psyche **7**, Suppl. I: 24.

Ball, E. D. 1907a. The genus *Eutettix* with especial reference to E. tenella, the beet leafhopper: A taxonomic, biologic and economic study of the North American forms. Proc. Davenport Acad. Sci. **12**: 27–94.

Ball, E. D. 1907b. The beet leafhopper (*Eutettix tenella*). Report of the Entomologist. Ann. Rept. Utah Agr. Expt. Sta. **16**: 16.

Ball, E. D. 1909. The leafhoppers of the sugar beet and their relation to the "curly-leaf" condition. U. S. Dept. Agr., Bur. Ent. Bul. (n.s.) **66**(4): 33–52.

Ball, E. D. 1917. The beet leafhopper and the curly leaf disease that it transmits. Utah Agr. Col. Expt. Sta. Bul. **155**: 1–56.

Gillette, C. P. and C. F. Baker. 1895. A preliminary list of the Hemiptera of Colorado. Colo. Agr. Expt. Sta. Bul. **31**: 1–37.

Oman, P. W. 1936. Distributional and synonymical notes on the beet leafhopper, *Eutettix tenellus* (Baker). Ent. Soc. Wash. Proc. **38**(7): 164–5.

Oman, P. W. 1948. Notes on the beet leafhopper, *Circulifer tenellus* (Baker) and its relatives (Homoptera: Cicadellidae). Jour. Kans. Ent. Soc. **21**: 10–14.

Oman, P. W. 1949. The Nearctic Leafhoppers (Homoptera: Cicadellidae). Ent. Soc. Wash. Memoir No. **3**.

Severin, H. H. P. and C. F. Henderson. 1928. Beet leafhopper, *Eutettix tenellus* (Baker) does not occur in the Argentine Republic. JOUR. ECON. ENT. **21**: 542–4.

Tests with Two Systemic Insecticides on Vegetable and Field Crops in Southern California[1,2]

H. T. Reynolds,[3] L. D. Anderson,[3] and J. E. Swift,[4] *University of California Citrus Experiment Station, Riverside*

A great deal of interest has developed in the use of systemic insecticides since Schrader (1946) demonstrated the ability of certain materials, particularly that of octamethyl pyrophosphoramide (schradan), to penetrate into the plant sap and thus to kill certain sucking insects. Ripper *et al.* (1950) explored the possibilities of this material in detail and reported it to be toxic as a systemic to 14 species of aphid, one of whitefly, one of mealybug, two of leafhopper, and two of red spider. They found, also, that it had little or no effect as a contact insecticide or fumigant against insects, and later (Ripper *et al.* 1951) pointed out the value of this selectivity in biological control.

Many other workers have reported the toxicity of systemic insecticides to various species of aphids and mites when solutions of these materials were sprayed on the plants, or poured on the soil, or used to soak seeds prior to planting.

Materials and Methods.—The pests and crops upon which field tests of systemic insecticides were made were the following: the cabbage aphid, *Brevicoryne brassicae* (L.), on cabbage plants; the pea aphid, *Macrosiphum pisi* (Kltb.), and strawberry spider mite, *Tetranychus atlanticus* McG., on alfalfa; the tulip bulb aphid, *Anuraphis tulipae* (Fonsc.), on carrot plants, the green peach aphid, *Myus persicae* (Sulz.), on sugar beet plants; onion thrips, *Thrips tabaci* Lind., on seed onion plants; the cyclamen mite, *Tarsonemus pallidus* Banks, on strawberry plants; and the whitefly *Trialeurodes abutilonea* (Haldeman) on cotton. Results of tests on cotton mites and on the cotton aphid are to be reported in detail at a later date.

The two systemic materials used in these tests were schradan (octamethyl pyrophosphoramide) and Systox, a product containing a mixture of 0-[2-(ethylmercapto)ethyl]-0,0-diethyl thiophosphate and S-[2-(ethylmercapto)ethyl]-0,0-diethyl thiophosphate.

On the different crops, sprays were applied at various concentrations and volumes. Different types of spray equipment were used in making applications. Because the cabbage, strawberry, and carrot plants were to be destroyed after completion of the tests, small plots were treated by means of hand-operated knapsack-type sprayers. Applications were made on alfalfa, sugar beet, and seed onion plants by means of a small self-propelled power sprayer having a 12-foot boom equipped with low volume nozzles.[5] Cotton plants were sprayed with a wheelbarrow-type sprayer equipped with a hand-operated spray gun.

In addition to sprays, the following systemic treatments were used on cabbage. Seeds were soaked 24 hours in solutions prior to planting in seed flats, young cabbage plants growing in seed flats were irrigated with solutions 4 days before transplanting, and solutions were poured around the base of cabbage transplants in the field.

The methods used to evaluate the insect or mite population following treatment are discussed briefly as each test is considered.

Control of the Cabbage Aphid on Cabbage Plants.—This systemic insecticide test was conducted at the Citrus Experiment Station, Riverside. On November 14, 1950, cabbage seeds were planted in seed flats 18 inches square and 4 inches deep, each containing about 4 inches (1,296 cubic inches) of soil. The young plants were transplanted into the field on January 5 and 8, 1951. Each treatment was replicated four times, and each replicate was a single row 55 feet long.

Treatments were as follows: (1) Seeds were soaked for 24 hours in a 1 per cent schradan solution or in a 0.5 per cent Systox solution. As soon as the seeds dried after removal from the solutions, they were planted in the seed flats. Plants from

[1] Paper No. 763, University of California Citrus Experiment Station, Riverside, California.

[2] Paper presented, in part, at the meeting of the Pacific Branch of the American Association of Economic Entomologists, Seattle, Washington, June, 1951.

[3] University of California Citrus Experiment Station, Riverside.

[4] Agricultural Extension Service, University of California, Berkeley.

[5] Teejet spray nozzles; Spraying Systems Company.

these seeds received no further insecticidal treatment in the field. (2) Four days prior to transplanting, one seed flat containing small cabbage plants was irrigated with 1,000 cc. of a 1 per cent schradan solution; another seed flat was irrigated with 1,000 cc. of 0.5 per cent Systox solution. (3) On January 24, two irrigation treatments were used on previously untreated transplants in the field. A 0.5 per cent schradan solution was poured around the base of each plant in a circle 4 inches in diameter, at the rate of 100 cc. per plant. A 0.25 per cent Systox solution was similarly applied to other plants. (4) On February 13, other transplants were given a single spray treatment of schradan or Systox. Application was made by means of a knapsack sprayer at the rate of about 100 gallons per acre. Technical schradan was applied at the rate of 1.4, 2, and 3 pounds per acre. Systox was applied at 0.5, 1, and 2 pounds per acre.

The total number of apterous aphids on 10 plants in each of the four replicates, or on a total of 40 plants per treatment, was determined. Aphid counts were made on February 16, March 5 and 15, and April 24.

Although plants grown from the seed soaked in the systemic solution remained free from aphids for some time in the seed flats, at time of transplanting into the field they had become uniformly infested. Thus, some control of aphids was indicated by this method, but by transplanting time, on January 5, the effect had dissipated. Results are summarized in table 1.

When seed flats were irrigated with solutions of schradan or Systox prior to transplanting, good control was obtained for two months (January 4 to March 5), but by March 15 the aphid reductions (from check) had dropped to from 59 to 67 per cent. At harvest time on April 24, the effect of schradan was completely gone and the effect of Systox nearly so (30 per cent reduction from check). The irrigation of transplants in the field with solutions of both systemic materials gave nearly perfect control (98 per cent) up to harvest time. The systemic sprays gave excellent aphid control. Forty days after the treatment the control for all spray concentrations ranged from 96 to 100 per cent. At the end of 50 days the control had only slightly decreased, and at harvest time (76 days after treatment) the control ranged from 32 to 79 per cent in the schradan-treated areas and from 51 to 85 per cent in the Systox-treated areas. In general, Systox appeared more effective than schradan for cabbage aphid control on cabbage.

CONTROL OF THE PEA APHID AND THE STRAWBERRY SPIDER MITE ON ALFALFA. —Three tests were conducted between February 28 and April 11, 1951, in the Imperial Valley, near El Centro. Each test was made on alfalfa in a different growth stage (very short to nearly mature).

In the first test Systox was applied at 0.5 and 1 pound of material per acre and schradan at 2.3 pounds per acre. Each treatment was replicated three times, and each replicate was a plot 70 feet long by 25 feet wide. Sprays in this test were applied at a rate of approximately 50 gallons per acre by a small power sprayer equipped with a 12-foot boom. Flat fan nozzles[5] were used, and the sprays were applied at a pressure of 200 p.s.i. The alfalfa was nearly mature at treatment time. In the second test the plots were the same size as in the first test but replicated four times. The systemic materials were applied with hollow cone nozzles[5] at about the same rates as in the first test but at approximately 25 and 50 gallons per acre. The alfalfa in this test was 4 to 6 inches high. The third test was similar to the first, except that the alfalfa was just beginning to grow after cutting, and hollow cone nozzles were used in making applications.

Aphid counts were made by sweeping the alfalfa with an insect net and counting the apterous aphids. Ten sweeps were made in each replicate. Mite counts were made by selecting leaflets which showed mite damage and counting all the living mites. These counts were based on 15 leaflets per replicate. Results are summarized in table 2.

The results obtained in these three tests indicated that both schradan and Systox gave good aphid and mite control, each material maintaining control for a period of 3 or more weeks. Aphid control appeared to be somewhat better when systemics were applied to nearly mature alfalfa than when applied to shorter alfalfa which was growing very rapidly. Mite control with Systox was outstanding at

Table 1.—Effect of schradan and Systox on control of the cabbage aphid, *Brevicoryne brassicae* (L.), on cabbage plants transplanted January 5 and 8, 1951, at Riverside, California.

Treatment		Surviving Apterous Aphids on 40 Plants per Treatment							
		February 16		March 5		March 15		April 24	
Date	Material and Amount	No.	% Reduction[1]	No.	% Reduction[1]	No.	% Reduction[1]	No.	% Reduction[1]
Jan. 4	Schradan[2a]								
	1,000 cc. 1% sol./flat.	72	90	221	81	920	59	711	0
	Systox[2a]								
	1,000 cc. 0.5% sol./flat	64	91	101	91	738	67	497	30
Jan. 24	Schradan[2b]								
	100 cc. 0.5% sol./plant	1	99+	2	99+	0	100	17	98
	Systox[2b]								
	Systox								
	100 cc. 0.25% sol./plant	0	100	0	100	0	100	15	98
Feb. 13	Schradan[2c]								
	1.4 lb./100 gal./acre	50	93	46	96	306	86	312	56
	2 lb./100 gal./acre	3	99+	11	99	175	92	487	32
	3 lb./100 gal./acre	0	100	2	99+	105	95	152	79
	Systox[2c]								
	0.5 lb./100 gal./acre	1	99+	2	99+	208	91	350	51
	1 lb./100 gal./acre	0	100	2	99+	25	89	286	60
	2 lb./100 gal./acre	0	100	0	100	1	99+	105	85
	None (check)	732	—	1142	—	2253	—	713	—

[1] From check.
[2] Method of Application:
(a) Irrigation in seed flat.
(b) Irrigation in field.
(c) In spray.

Table 2.—Effect of Systox and schradan sprays on control of the pea aphid, *Macrosiphum pis* (Kltb.), and the strawberry spider mite, *Tetranychus atlanticus* McG., on alfalfa in various stages of growth near El Centro, California, 1951.[1]

Spray Treatment			Apterous Aphids (10 Sweeps of Insect Net per Replicate)				Mites (15 Leaflets per Replicate)			
Material	Pounds per Acre	Gallons per Acre	Mar. 7	Mar. 14	Mar. 21	Mar. 28	Mar. 14	Mar. 21	Apr. 4	Apr. 11
Test 1—Alfalfa nearly mature; treated February 28 (3 replicates per treatment)										
None (check)	—	—	13,017	11,000	19,151	10,192	2,183	1,685	284	
Systox	0.5	53	61	91	1,491	2,080	62	21	55	
Systox	1.0	49	14	59	736	1,744	20	2	44	
Schradan	2.3	57	243	237	1,533	3,672	1,146	475	236	
Test 2—Alfalfa 4–6 inches high; treated March 13 (4 replicates per treatment)										
None (check)	—	—				56,626			461	541
Systox	0.43	43				8,128			15	44
Systox	0.5	25				7,400			17	21
Systox	1.0	25				4,680			1	6
Schradan	2.0	25				4,504			68	69
Test 3—Alfalfa 1–2 inches high; treated March 20 (3 replicates per treatment)										
None (check)	—	—				21,952				
Systox	0.5	50				1,896				
Systox	1.0	50				1,036				
Schradan	2.0	50				1,474				

[1] Alfalfa cut March 22. No aphid counts were made after March 28, hot weather and predaceous insects having cleaned up the population.

both 0.5 and 1.0 pound per acre and appeared to be better than with schradan at 2.0 pounds per acre. There was no difference in the aphid and mite control when 0.5 pound of Systox was applied at 25 gallons per acre and when 0.43 pound of this material was applied at 43 gallons per acre.

CONTROL OF THE TULIP BULB APHID ON CARROT PLANTS.—This systemic test was begun in March, 1951, in the Holtville area of the Imperial Valley. The tulip bulb aphid is very difficult to control on carrots because of its location on the plant. The early infestation is very deep in the plant crown, and as the infestation increases it spreads up on the leaves. Because of the inaccessibility of this aphid, control with ordinary insecticidal dusts and sprays is difficult; hence the tests with systemic insecticides.

Since the carrots were to be destroyed at harvest time, small plots were treated. Each treatment was replicated four times on plots 10 feet long and one bed (two rows) wide. Applications were made by a hand-compression sprayer and only the plant tops were wet. Schradan was applied at 2 pounds of material per acre, and Systox at 0.5 and 1.4 pounds per acre.

The carrots were treated on March 16 and examined on March 23, March 28, and April 26. Total numbers of aphids were counted on 4 plants per replicate, or on a total of 16 plants per treatment, except at harvest time (April 26), when 30 plants were examined per treatment. Results are summarized in table 3.

Only fair aphid control resulted from applications of systemic material. Systox at the higher dosage gave control about equal to that of schradan at 2 pounds per acre. The lower dosage of Systox gave inferior results. At harvest time (April 26) there was little difference in the number of aphids on treated and untreated carrots. As only the carrot tops were wet by the treatment in this test, there was little if any aphid mortality as a result of contact action. The mediocre aphid control obtained in this test may indicate that in plants such as carrots large amounts of the systemic material are translocated into the large roots.

Table 3.—Effect of Systox and schradan sprays on control of the tulip bulb aphid, *Anuraphis tulipae* (Fonsc.), on carrot plants in the Imperial Valley, California, 1951.

Spray Treatment, March 16			Average Number of Aphids per Plant		
Material	Pounds per Acre	Gallons per Acre	Mar. 23	Mar. 28	Apr. 28
None (check)	—	—	126	167	9
Systox	0.5	50	70	93	10
Systox	1.4	68	25	20	12
Schradan	2.0	49	24	45	3

CONTROL OF THE GREEN PEACH APHID ON SUGAR BEET PLANTS.—This systemic test was begun in February, 1951, in the Imperial Valley. At treatment time the sugar-beet tops were large; the tap roots were only about 1.5 inches in diameter but were growing rapidly.

The sprays were applied at the approximate rate of 50 gallons per acre by a small power sprayer equipped with a 12-foot boom. Each treatment was replicated twice and each replicate was 50 feet long by four beds (eight rows) wide (14 feet). Technical schradan was applied at the rates of 1.1, 1.5, 3.5, and 2.0 pounds per acre. In addition, the spray at the 2-pound dosage contained 5 ounces of a wetting agent[6] per 100 gallons. Systox was applied at 0.55, 0.9 and 1.4 pounds of material per acre.

The treatments were evaluated on February 20 by counting the number of aphids on 25 leaves per replicate or on a total of 50 leaves per treatment. A second aphid count was not made, but on March 23 the plants in each treatment were rated as to whether or not they showed signs of having had a severe aphid infestation. Results obtained are summarized in table 4.

In this test Systox at all dosages gave excellent aphid control, but that obtained with schradan was poor. The addition of a wetting agent to the schradan seemed to reduce its effectiveness. The difference in control obtained with Systox and schradan may be due in part to the high initial kill obtained with Systox, as compared with little or no initial kill with schradan, rather than to the systemic action of these materials. This tends to substantiate the indication obtained in the test on carrots, that much of the systemic materials may

[6] *Multifilm L*, a spreader and deposit builder manufactured by Colloidal Products Corporation.

Table 4.—Effect of Systox and schradan sprays on control of the green peach aphid, *Myzus persicae* (Sulz.), on sugar beet plants near El Centro, California, 1951.

Spray Treatment, February 15				
Material	Pounds per Acre	Gallons per Acre	Aphids per 50 Leaves, Feb. 20	Plants Showing Injury, March 23[1]
None (check)	—	—	3,894	393
Schradan	1.1	55	2,697	431
Schradan	1.5	39	1,720	257
Schradan	3.5	44	1,907	246
Schradan[2]	2.0	51	3,670	281
Systox	0.55	55	30	43
Systox	0.9	46	44	13
Systox	1.4	46	14	27

[1] Total number of plants in four rows of each replicate showing signs of having had severe aphid infestation.
[2] Plus 5 ounces *Multifilm L* (spreader and deposit builder manufactured by Colloidal Products Corporation) per 100 gallons.

be translocated and held in the large root.

CONTROL OF ONION THRIPS ON SEED ONION PLANTS.—Systemic materials were compared with standard insecticides for control of onion thrips on seed onions in the Imperial Valley. Each treatment was replicated four times and each replicate was four beds (eight rows) wide and 50 feet long. Applications were made by a small power sprayer equipped with a 12-foot boom. Two flat-fan spray nozzles[5] were used per onion bed (one per row). Treatment evaluations were made by counting all the thrips on 4 plants per replicate, or a total of 16 plants per treatment. Results are summarized in table 5.

In this test neither schradan nor Systox gave good control of onion thrips on seed onions. Systox gave some initial kill (65 per cent reduction from the check 5 days after treatment), but by the time of the second count (14 days later) there was only a 12 per cent reduction. Schradan, which has little contact action, gave poor results in both counts. When compared with standard insecticides (DDT and toxaphene), which gave from 90 to 92 per cent reduction 5 days after treatment, and from 81 to 83 per cent reduction at 14 days, there appears to be little control of thrips by systemic action with either schradan or Systox on onions.

Table 5.—Effect of standard and systemic sprays on control of the onion thrips, *Thrips tabaci* Lind., on seed onion plants in the Imperial Valley, California, 1951.

			Thrips on 16 Plants per Treatment			
			March 14		March 23	
Spray Treatment, March 9						
Material	Pounds per Acre	Gallons per Acre	Number	Per Cent Reduction from Check	Number	Per Cent Reduction from Check
None (check)	—	—	955	—	3,062	—
DDT	1.8	30	79	92	528	83
Toxaphene	3.6	30	92	90	584	81
Systox	0.6	30	338	65	2,688	12
Schradan	2.4	30	638	33	1,970	36

CONTROL OF THE CYCLAMEN MITE ON STRAWBERRY PLANTS.—This test was carried out in the Azusa area on Donner variety strawberry plants that were heavily infested with cyclamen mites. Schradan and Systox were applied on May 15, 1951, at 50 gallons per acre with a knapsack-type sprayer. Schradan was applied at 2 pounds per acre and Systox was applied at 1 and 2 pounds per acre. Plots were one row wide and 20 feet long, and each treatment was replicated four times. The treatments were examined for effectiveness on May 22 and June 4, and little or no reduction in the cyclamen mite population was observed on either date.

CONTROL OF THE WHITEFLY ON COTTON PLANTS.—Schradan was applied to cotton for control of the whitefly, near Indio, on October 3, 1950. Applications were made by a wheelbarrow-sprayer operating at a pressure of 300 p.s.i., using a spray gun equipped with a No. 3 nozzle disk. Four replications were made, and each replicate was 15 feet long. In each plot one row was sprayed to the point of runoff, and several rows were sprayed lightly over the plant tops. The following treatments were used: 1 and 2 pints of schradan (33 per cent schradan plus 67 per cent emulsifier) to 100 gallons of water; 1 and 2 pints of technical schradan to 100 gallons of water; and check. Examination of treated and untreated leaves on October 6, 3 days after treatment, indicated that no mortality or reduction in number of whitefly nymphs was obtained from any treatment. A subsequent examination was made on October 17, but the whitefly population had been almost completely eliminated over all the treatment area by parasites.

SUMMARY.—A study has been made of the relative effectiveness of schradan (octamethyl pyrophosphoramide) and of

Systox, a product containing a mixture of 0-[2-(ethylmercapto)ethyl]-0,0-diethyl thiophosphate and S-[2-(ethylmercapto)-ethyl]-0,0-diethyl thiophosphate, for control of several insects and mites infesting various vegetable and field crops.

Excellent control of the cabbage aphid, *Brevicoryne brassicae* (L.), on cabbage plants was obtained with both materials. Plants grown from seeds soaked in systemic solutions remained free from aphids in seed flats for some time but became infested prior to transplanting. Irrigation of young plants in seed flats with systemic solutions applied prior to transplanting gave excellent control for 2 months. Systemic solutions applied to the base of newly set plants gave excellent control up to harvest time. Schradan sprays (1.4 to 3 pounds per acre) and Systox sprays (0.5 to 2 pounds per acre) gave excellent control for 50 days, but 76 days after treatment control on the schradan-treated plants ranged from 32 to 79 per cent reduction from the check, and on the Systox-treated plants from 51 to 85 per cent.

Excellent control of the pea aphid, *Macrosiphum pisi* (Kltb.), and of the strawberry spider mite, *Tetranychus atlanticus* McG., was obtained on alfalfa with these materials. Aphid control appeared to be better on nearly mature plants than on shorter, rapidly growing plants. Mite control was outstanding with Systox at 0.5 and 1.0 pound per acre and was better than that obtained with schradan at 2 pounds per acre.

In a test for control of the tulip bulb aphid, *Anuraphis tulipae* (Fonsc.), on carrots, fair to good results were obtained. Schradan at 2 pounds per acre gave about the same results as Systox at 1.4 pounds per acre. Systox at 0.5 pound per acre gave only fair results.

Control of the green peach aphid, *Myzus persicae* (Sulz.), on sugar beet plants was excellent with Systox at dosages ranging from 0.55 to 1.4 pounds per acre, but was poor with schradan at dosages ranging from 1.1 to 3.5 pounds per acre. This difference probably occurred because of the high initial kill with Systox, whereas the initial kill with schradan is low. This test and the test on carrots indicate that on crops such as these, having tap roots, large amounts of the systemic materials may be translocated and held in the root.

Neither schradan nor Systox gave good control of the onion thrips, *Thrips tabaci* Lind., on onions, although there was a fair initial reduction of the thrips population with Systox.

There was little or no reduction in populations of the cyclamen mite, *Tarsonemus pallidus* Banks, on strawberry plants following applications of Systox at 1 and 2 pounds per acre or of schradan at 2 pounds per acre.

Schradan sprays applied to the point of runoff on cotton plants for control of the whitefly *Trialeurodes abutilonea* (Haldeman) gave no reduction of the whitefly nymphs.

LITERATURE CITED

Ripper, W. E., R. M. Greenslade and G. S. Hartley. 1950. A new systemic insecticide bis(bis dimethylamino phosphonous) anhydride. Bul. Ent. Res. **40**(4): 481–501.

Ripper, W. E., R. M. Greenslade and G. S. Hartley. 1951. Selective insecticides and biological control. JOUR. ECON. ENT. **44**(4): 448–59.

Schrader, G. 1946. Nitrogen-containing phosphoric acid derivatives as contact insecticides and materials for the internal therapy of plants. [Free translation from the German.] British Intelligence Objectives Sub-committee Final Report No. 1095 (Memorandum C. 3., pp. 45–50), London.

Studies of Mites and Their Control on Pecan in Louisiana

W. C. Pierce,[1] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Observations on mite injury to pecan in Louisiana were begun in July 1946 during an outbreak in an orchard near Shreveport on trees that had been sprayed with DDT. The species found was described later as *Tetranychus hicoriae* McGregor. This pest probably caused most of the mite injury observed on pecan in Florida by Walker in 1931, and workers in Mississippi had submitted specimens for determination prior to 1946. Various investigators in Florida, Georgia, and Texas have since reported damage by this mite and studies on its control. Nickels (1942) reported on two other species of mites, *Eriophyes caryae* Kieffer and *Paratetranychus viridis* (Banks), as pests of pecan. These three species and two additional species, *Brevipalpus* sp. and *sayedi* Baker, are commonly found attacking pecans in Louisiana. The biology of these mites was not studied in detail, but observations were made during the period 1946–1952 on their habits, injury caused to pecan, and the effectiveness of different acaricidal treatments against the more important species.

Habits and Injury Caused to Pecan. —*Tetranychus hicoriae* may be found on both surfaces of pecan leaflets, but it seems to feed and reproduce principally on the under surface. Its feeding causes the leaflets to scorch, especially in hot, dry weather. In heavy infestations the scorched leaflets may fall prematurely. Fresh scorch injury appears as dark brown or liver-colored blotches in the leaflets, and old scorch injury as dead areas of irregular size and pattern in leaflets that do not fall from the trees. The liver-colored scorch is usually the first indication of a heavy build-up of these mites. Much of the foliage remaining on the trees after heavy infestations may be russeted or scorched.

Brevipalpus sp. and *B. sayedi* are usually found on the under side of the leaflets close to the veins. In heavy infestations the veins and adjoining tissue turn brown. The shucks of the nuts are also attacked and may become russeted in appearance.

Paratetranychus viridis may be found on both surfaces of the leaflets, but it appears to feed and reproduce principally on the upper surface. In heavy infestations this surface becomes greyish-white from feeding injury and accumulations of egg shells and cast skins of the immature mites.

Eriophyes caryae begins feeding on the margin of the leaflets, causing it to fold or roll and thus form a thickened gall-like growth parallel to the mid-vein. The tiny mites can be found in large numbers within this gall-like growth.

Tetranychus hicoriae was the most important species of mite observed on pecan. Severe infestations occurred under various conditions in orchards scattered throughout northern Louisiana. Heavy infestations sometimes developed following the use of sprays of DDT and other insecticides. However, since many of the severe infestations observed on pecan have been in unsprayed orchards, it is possible that much of the injury by this mite in past years either was not recognized or was attributed to other causes. Severe infestations of this pest have usually caused premature losses of foliage from large numbers of planted orchard and top-worked pecan trees.

Some of the orchards in which severe infestations of *Tetranychus hicoriae* were observed were also heavily infested with black pecan aphids, *Melanocallis caryaefoliae* (Davis), and the two species of *Brevipalpus* mites. These mites did not cause extensive losses of foliage, but the foliage on heavily infested trees appeared weakened and very susceptible to damage by *hicoriae*. Heavy infestations of *Eriophyes caryae* and *Paratetranychus viridis* were also observed, but less frequently, and no serious defoliation was noted.

Full-grown females of *Brevipalpus* sp., *B. sayedi*, and *Tetranychus hicoriae* overwinter in protected places on the trees. The first two species were taken in large numbers from beneath old coverings of

[1] The writer is indebted to E. A. McGregor (retired) and to other specialists in the Bureau of Entomology and Plant Quarantine for identifying the different species of mites. He is also indebted to local pecan growers, members of the Bureau of Plant Industry, Soils, and Agricultural Engineering, and representatives of insecticide companies for their cooperation in this work.

the obscure scale, *Chrysomphalus obscurus* (Comst.), and from crevices in the bark on the small outer branches of pecan, and *T. hicoriae* from beneath rough bark on the main branches and trunk. A fourth species, identity uncertain, overwinters in the egg stage on the twigs and small branches.

Each of these mites becomes active and begins attacking the foliage soon after the trees initiate growth in the spring. The earliest date on which leaf-scorch injury by *Tetranychus hicoriae* was observed in the Shreveport area was April 10. However, it did not cause serious scorching until the latter part of June. Light injury to the leaflet veins by *Brevipalpus* sp. and *B. sayedi* was observed as early as May 19. Injury or dwarfing of foliage by *Eriophyes caryae* became very pronounced on heavily infested trees by the early part of May.

The life history and the number of generations of *Tetranychus hicoriae* during the year were not studied in detail, but the egg and other stages were observed on pecan foliage from April until late in October. The number of mites observed on an individual leaflet ranged from one to more than a hundred, depending on the time of year and the conditions of infestation. Apparently, a single female mite may cause a small tender leaflet to scorch early in April, but 10 to 60 mites may be required to effect scorching of more mature leaflets later in the season. Scorching in April appeared to be confined to leaves on shoots arising from small branches and water sprouts attached to the main branches and trunks of the trees. The mite infestation spread throughout the tree later in the season, but serious scorching of foliage and premature defoliation began on the lower portions of the trees. Severe infestations were observed from late in June to early in October, but most of the damage occurred during July, August, and September. In most of the orchards heavy losses of foliage in August and early September have resulted in failure of the trees to bloom properly the following spring.

CONTROL TESTS.—In preliminary tests conducted during August 1946 a 1-per cent summer-oil emulsion failed to control heavy infestations of *Tetranychus hicoriae* on Stuart pecan trees. Other tests were begun on June 26, 1947, on small plots of Schley and Mahan pecan, with the following sprays (materials per 100 gallons):

Wettable sulfur 6 pounds plus dinitro-o-cyclohexylphenol (a DN compound) (40% wettable) 0.6 pound.
HETP (50%) 1 pint.
HETP (100%) ½ pint.

The mite infestation was sufficiently heavy to cause considerable scorching of foliage before the treatments were applied. Infestation counts were not obtained, but 8 days after the application it was difficult to find mites on foliage of trees that received the sulfur-DN treatment. The infestation on trees sprayed with HETP appeared to be about as heavy as was observed prior to the treatment. In July the sulfur-DN spray was used on these trees and also on a large group of Success trees being used in tests on other pecan pests. A single application appeared effective, since *Tetranychus hicoriae* caused no further damage to these trees during the remainder of the season.

In 1948 and 1949 *Tetranychus hicoriae* caused practically no damage on trees treated late in the summer with parathion for the control of the black pecan aphid. This applied to conventional-type spray of 25 per cent wettable powder, 1 pound to 100 gallons, and concentrated mist sprays, 6 pounds to 115 gallons. Sprays of wettable sulfur, alone and in combination with the DN compound, gave good results against heavy infestations in two orchards in 1949.

In August 1950 tests were conducted with the following sprays against *Tetranychus hicoriae* on Success pecan trees:

Wettable sulfur 5 pounds plus dinitro-o-cyclohexylphenol (a DN compound) (40 per cent wettable) 0.63 pound to 100 gallons.
Parathion (25 per cent wettable) 0.63 pound to 100 gallons.
Parathion (25 per cent wettable) 6 pounds, copper sulfate 20 pounds, and lime 6 pounds to 115 gallons.

The first two treatments were applied with a conventional hydraulic sprayer and the third with a mist blower. Examination under a microscope of 40 leaflets from trees receiving each treatment showed 99 per cent mortality of mites on leaflets treated with the sulfur-DN spray, 91 per cent on those treated with the parathion conventional spray, and 90 per cent on leaflets receiving the parathion concentrated spray. A total of 1,200 to 1,700

mites was found in each 40-leaflet sample. It is believed that some of the mites surviving treatments of parathion were *Brevipalpus* sp., since subsequent observations have indicated that parathion is not effective against this species.

Further tests in August and September 1950 indicated that it might be possible to add parathion to the DDT spray used to control the pecan weevil (*Curculio caryae* (Horn)) and thus prevent a build-up of mites. In 1951 tests were conducted on Schley pecan trees to compare the effectiveness of parathion, parathion plus wettable sulfur, and EPN in preventing mite injury when combined with DDT and a fungicide. The materials used (pounds per 100 gallons) and the dates of application were as follows:

(1) Ziram 2, DDT (50% wettable) 2, parathion (15% wettable) 1, plus wettable sulfur 4; applied on May 22, June 30, and without ziram on August 6.
(2) Copper sulfate 6, lime 2, DDT (50% wettable) 2, parathion (15% wettable) 1; applied on May 22, June 30, and without bordeaux mixture (copper sulfate and lime) on August 6.
(3) Copper sulfate 6, lime 2, DDT (50% wettable) 2, BHC (10% gamma wettable) 1, EPN (27% wettable) ¾ to 1; applied on May 23, June 30, and without bordeaux mixture on August 6.
(4) Copper sulfate 6, lime 2, DDT (50% wettable) 2, BHC (10% gamma wettable) 1; applied on May 18–26, June 27–July 5, and followed by DDT (50% wettable) 2, BHC (10% gamma wettable) 1, and wettable sulfur 5 early in August.

Treatment 4 was used by the grower on most of the productive Schley trees in the orchard in which the tests were conducted. However, some of the trees failed to set nuts and were not sprayed during the season.

The insecticides used in these tests were very effective against a heavy infestation of the pecan nut casebearer (*Acrobasis caryae* Grote). Pecan scab was not a serious problem on Schley trees in this orchard under drouth conditions; therefore the fungicide was included in only two sprays. The black pecan aphid caused very little injury on either the sprayed or unsprayed trees throughout the season. Three species of mites became very numerous in the orchard. Injury to the leaflet veins by the two species of *Brevipalpus* was very pronounced on many trees prior to June 30, and there was a general build-up in the population of *Tetranychus hicoriae* throughout the orchard late in July and in August.

On September 25–28 two hundred leaflets were examined on each of five or more trees in the four treated plots and also on ten untreated trees to determine the extent of injury to foliage by *Tetranychus hicoriae*. A schedule of three applications of parathion and wettable sulfur (treatment 1) was the most effective, as only 5 per cent of the leaflets were injured by this mite. However, early applications of this treatment did not prevent the need for the third acaricidal spray in August. Schedules of three applications of parathion (treatment 2) or EPN (treatment 3), and a single application of wettable sulfur (treatment 4) appeared adequate in preventing serious premature losses of foliage by this mite, 10 per cent being injured by treatments 2 and 3 and 16 per cent by treatment 4. The untreated trees showed about 50 per cent injury. The treated trees retained most of their foliage until November.

Counts of *Brevipalpus* sp. and *B. sayedi* between August 15 and 22 on samples of 25–100 leaflets per treatment and observations in September on injury to leaflets indicated that treatment 1 was fairly effective in preventing injury by these mites. A single application of wettable sulfur in August reduced infestations of these species, but there was already some injury to the foliage.

In 1952 tests were conducted on Schley pecan trees in two orchards to study the effectiveness of different acaricides in preventing mite injury when used in combination with various spray materials applied for the control of insects and diseases. The materials used (pounds per 100 gallons) and the dates of application in orchard No. 1 were as follows:

(1) Copper sulfate 6, lime 2, DDT (50% wettable) 2, parathion (15% wettable) 1, wettable sulfur 4; applied on May 26.
(2) Copper sulfate 6, lime 2, DDT (50% wettable) 2, BHC (12% gamma wettable) 1, wettable sulfur 4; applied on May 26 and without bordeaux mixture and DDT on September 4.
(3) Copper sulfate 6, lime 2, DDT (50% wettable) 2, BHC (12% gamma wettable) 1, Aramite (15% wettable) 1.5; applied on May 26 and without bordeaux mixture and DDT on September 4.

A severe infestation of the two species of *Brevipalpus* mites developed during July and August on trees that received

treatment 3. On October 20–21 one hundred leaflets were examined on each of eight trees in the three treated plots to determine the extent of injury to foliage by these mites. These examinations indicated that wettable sulfur and wettable sulfur combined with parathion gave good results in preventing foliage injury by *Brevipalpus* sp., since 14 per cent of the leaflets were injured on trees sprayed with treatment 1, 6 per cent with treatment 2, and 64 per cent with treatment 3. Infestations of *Tetranychus hicoriae* tended to build up on the sprayed trees during the latter part of August, but they caused no appreciable damage.

Similar results were obtained against mites in orchard No. 2 on trees used in experiments conducted in cooperation with C. L. Smith, Bureau of Plant Industry, Soils, and Agricultural Engineering. In late October 7 per cent of the leaflets examined were injured by *Brevipalpus* sp. mites on trees sprayed on April 18, May 9, June 2, and August 13 with wettable sulfur 4 pounds plus parathion (25 per cent wettable) 1 pound in combination with sprays of 4-1-100 and 6-2-100 bordeaux mixture. From 42 to 59 per cent of the leaflets examined were injured by these mites on trees sprayed four times with three different fungicidal treatments in which parathion (25% wettable) 1 pound to 100 gallons was included in the last application on August 13. The percentages are based on counts of 100 leaflets per tree with six replications. *Tetranychus hicoriae* caused little or no injury to foliage on any of the treated trees.

Studies were made in three orchards on Stuart variety pecan trees during August and September 1952 to determine the effectiveness of aeroplane applications of concentrated parathion spray against heavy infestations of *Tetranychus hicoriae*. This spray was applied on 52, 25, and 22 acres of pecans, at the rate of 1 pound of parathion ($\frac{1}{2}$ gallon of 25-per cent liquid formulation) in 5 gallons of spray per acre. Preliminary observations indicated that active stages of the mite were affected first and that 3 or more days were required for maximum results against mites hatching from eggs. A total of 1,081 dead and 16 live mites were found on 30 leaflets taken from trees in one of these orchards approximately 24 hours after the treatment. On three additional samples of 30 to 40 leaflets taken after one to two weeks, the numbers of live mites observed were 93, 22, and 46. Most of the 93 mites observed in the first of these samples were found on three heavily infested leaflets. In the two remaining orchards 98.7 and 97.8 per cent of the mites observed were dead on samples of 50 and 30 leaflets taken from the trees 3 to 4 days after the application. Most of the surviving mites were newly hatched. The total numbers of mites observed on these samples were 4,395 and 2,772. Twenty-six live mites were found on a sample of 50 leaflets taken from the third orchard 10 days after the application.

The treatment used in this study gave excellent results against a severe infestation of the black pecan aphid in the first orchard, but some of the trees became reinfested after three to four weeks. A single application seemed sufficient for the remainder of the season against *Tetranychus hicoriae*.

In late August and early September 1952, observations were made in two orchards on Stuart and other pecan varieties to determine the effectiveness of a dust containing 1 per cent of parathion and 40 per cent of sulfur against *Tetranychus hicoriae*. The dust was applied with a ground duster in one orchard and with an aeroplane in the second orchard, at the rate of approximately 50 to 55 pounds per acre. It appeared more difficult to obtain satisfactory distribution of the dust on large pecan trees with the aeroplane than with the duster operated on the ground. Preliminary examinations of small samples of infested leaflets from trees treated from the ground indicated that active stages of the mite were killed within the first 36 hours but that 3 or more days were required to obtain good results against young mites hatching from eggs. This treatment held the mite in check for about 3 weeks. Similar results were obtained by the grower with conventional sprays containing parathion and wettable sulfur. In the orchard treated by aeroplane, 99 per cent of 1,951 mites observed were dead on a sample of 50 leaflets taken from treated trees 2 days after application. On a second sample of 50 leaflets taken from these trees 45 live mites were found after 10 days. Further tests were conducted which indicated that a dust

containing 40 per cent of sulfur in combination with BHC has value for use against *Tetranychus hicoriae*, but it appeared to act slowly against mature stages of the pest.

DISCUSSION AND CONCLUSIONS.—The results obtained in 1952 with aeroplane applications of concentrated sprays of parathion against *Tetranychus hicoriae* appear promising, but caution must be exercised in the use of this treatment until more information is obtained. Further study is needed to determine the proper rate of application per acre, the effectiveness of the spray against other pecan pests, and under what conditions this spray is safe and practical for use on pecans. Equipment manufacturers have just begun producing a satisfactory machine for applying concentrated sprays on pecan from the ground, and studies are needed to compare the effectiveness of concentrated sprays applied from the ground with those applied from an aeroplane.

A dust containing 1 per cent of parathion was found to give good results against the black pecan aphid in 1947. This dust has continued to be effective against this pest in two orchards in northwest Louisiana when applied from the ground at the rate of 50 to 55 pounds per acre. From these results and those obtained in 1952 against *Tetranychus hicoriae* it appears that thorough applications of a dust containing 1 per cent of parathion and 40 per cent of sulfur may prove practical for use against these pests on pecan. Most of the dust applications on pecan in Louisiana were made during early morning, 5 to 8 A.M., when air conditions were favorable.

It is frequently desirable for pecan growers in northern Louisiana to use materials or combinations of materials that are effective against mites, the black pecan aphid, and other insect pests in combination with fungicides applied for the control of diseases. A combination of wettable sulfur and parathion has appeared very satisfactory against three species of mites when used in sprays containing a fungicide and other insecticides. Parathion is effective against *Tetranychus hicoriae* and the black pecan aphid, but it may be possible to substitute other materials for parathion if special conditions warrant this procedure. These studies indicate that one acaricidal spray applied in the latter part of May, followed by one or more applications as needed in July, August, or September, may be required for good results against the three most important species of mites attacking pecan. In many instances one to two acaricidal sprays were required to prevent damage by *Tetranythus hicoriae* during July, August, and September.

LITERATURE CITED

Nickels, C. B. 1942. Two economic species of mites on pecan. JOUR. ECON. ENT. 35(6): 948.

Retentive Toxicity of Field-Weathered Insecticide Residues to Entomophagous Insects Associated with Citrus Pests in California[1]

BLAIR R. BARTLETT, *Department of Biological Control, University of California Citrus Experiment Station, Riverside*

The increase in populations of citrus pests formerly held inconspicuously in favorable biological balance has been one important effect of treatment with many of the newer, persistent-residue types of contact insecticides. Another general effect has been an exceptionally rapid flareback of treated pests following initial control. Both are consequences of the chemical destruction of natural enemies. The first type of disturbance usually calls for the application of still another material; the second, by shortening the holding period between treatments, commonly results in more frequent applications of the same material that initiated the upset.

Integrated programs of pest control

[1] Paper No. 762, University of California Citrus Experiment Station, Riverside, California.

complementary to both biological and chemical control often can be devised if an assessment has been made of the preferential toxicities to pest and natural enemies, and if the most advantageous manner and time of treatment have been investigated. This ecological approach offers a productive means of diminishing the general severity of insect pest problems.

As the basis for an ecological approach to citrus pest control problems, a survey has been made of the comparative toxicities and of the persistence of the residual toxicities of a number of insecticides to three species of representative entomophagous insects associated with California citrus pests. Most of the materials currently applied commercially for control of citrus pests in California have been included in this bioassay of toxic residues.

MATERIALS AND METHODS.—The three species of entomophagous insects used in the bioassay were chosen as representative of various degrees of vigor among beneficial insects of citrus pests. Their relative susceptibility enables one better to estimate possible untested conditions of weathering and dosage of the pest control materials. *Aphytis chrysomphali* (Mercet) [Aphelinidae] is an extremely delicate external parasite predominantly attacking the California red scale, *Aonidiella aurantii* (Mask.). *Metaphycus helvolus* (Comp.) [Encyrtidae] is a more robust internal parasite primarily attacking the black scale, *Saissetia oleae* (Bern.). *Lindorus lophanthae* (Blaisdell) [Coccinellidae] is a small but hardy ladybeetle which is a general feeder upon diaspine scale insects.

Thirty-five commercially employed pest control formulations were used in the tests. Some few materials were used at various dosages or formulations, according to common commercial practice. Application methods employed were those consistent with field practice. Only in the dust applications were there deviations from common application procedures, rotary hand dusters being used to ensure uniform dosages and coverage. Attempts were made to apply all materials at periods comparable to those employed in commercial operations. Some slight variations from normal timing schedules were at times necessary, however, to avoid periods of rainfall. Weathering, with a single exception, was without rainfall exposure in order to minimize indeterminate variables.

For bioassay of residual toxicity, five or more selected flat leaves were picked from the outer 6-inch periphery of field-treated trees for test with each species at each period of toxic residue assessment. The assessments were made after periods of field weathering of 1 day, 1 week, 1 month, 3 months, and 5 months,

FIG. 1.—One hundred modified Munger cells set up for insecticide residue bioassays of citrus leaves, showing suction-tube arrangement for preventing vapor accumulation and for maintaining constant temperature and humidity within the cells.

or until toxicity had been lost. The test apparatus employed was that described by Bartlett (1951) for testing dust residues; it consisted of modified Munger cells constructed of plastic and exposing 10-cm.^{2} areas of leaf surface. Three to four air changes per minute in the cells prevented vapor accumulation, and air drawn from the room made it possible to maintain the cells at 80° F. and 50 per cent R.H. For each weathering period and test species, five or more cells, each containing approximately 35 individuals of *Metaphycus helvolus*, or 50 of *Aphytis chrysomphali*, or 10 of *Lindorus lophanthae*, supplied the bioassay data. The insects were placed in the cells after ether inactivation. A thin film of honey on the upper cell surface supplied necessary food. One hundred cells set up for operation are pictured in figure 1.

In these studies toxicity is presented (Table 1) as the number of hours of confinement required to give 50 per cent kill of the total insects in the five cells after correction for natural mortality by Abbott's (1925) formula. The figure ">100" (greater than 100) represents a kill of fewer than 50 per cent after 100 hours. Concurrent field surveys with DDT and parathion residues have established that some reproduction of the test species is possible at this residue level, whereas greater residues result in rapid death of immigrants. Comparative toxicities of residues inducing less than 50 per cent kill after 100 hours are indicated by their relative positions from high to low toxicity (Table 1).

The majority of the 35 pest control formulations bioassayed were primarily contact poisons. Cryolite is the only relatively insoluble stomach poison insecticide material now applied to citrus in California. This type of material would be expected to exert its influence upon predaceous species primarily by their ingestion of solid particles adhering to host material —a condition not represented in the present tests. Methods employed in the present tests with tartar emetic-sugar, and possibly with sabadilla-sugar, probably did not adequately test one condition which might occur under field conditions namely, the contamination, at the time of application, of the natural honeydews which serve as food for adult natural enemies.

The toxicity displayed by dust materials was somewhat variable at times because of periods of natural aridity preceding the bioassays and, to a limited extent, because of the presence on leaf samples of deposits of windblown road dust, which had a definite effect upon the test insects (Bartlett 1951). Control leaf samples were obtained from trees waterwashed at the time of application of test materials to neighboring trees, thus minimizing discrepancies from this source. The physical effects of dry powder residues are indicated by the high toxicity of pyrophyllite dust. Hydrated lime, although showing less than 50 per cent kill after 100 hours of exposure in all tests consistently demonstrated a toxicity nearing 50 per cent kill, even after residue-weathering periods of three months after application.

Very little specificity to different beneficial species was demonstrated in the tests. A very slight sensitivity of *Metaphycus helvolus* to sulfur materials was evident. Oils displaying a trapping effect varying with the viscosity of the oil and the delicacy of the test species. Coccinellid and neuropteroid predators, as well as certain parasitic Hymenoptera, have shown sensitivity to a number of insecticides in field trials (DeBach & Bartlett 1951). Chlordane, which has been found[2] to be fairly toxic to certain parasitic Hymenoptera under confined conditions, showed a disproportionately low toxicity to the test species examined in the present tests, where aeration was continuous.

Repellency effects of the insecticidal residues upon beneficial insects were poorly evaluated by the test methods used in this study. However, a tendency on the part of the parasitic species concerned to avoid residues of the dinitro materials was clearly demonstrated.

DISCUSSION.—Any bioassay of field-weathered residues, although faithfully representing the conditions of the particular treatment applied and tested, is not always a satisfactory picture of results with the same material and dosage under slightly different weathering conditions. It was evident in this and related studies, particularly with parathion, chlordane, and dinitro dust materials, that residues may be very quickly dissipated during periods of high temperature and intense sunlight. Residues of the same materials may be very tenacious if applied during the fall or winter months. These three materials, and possibly EPN and bis (*para*-chlorophenoxy) methane, are indicated as subject to great variability in weathering. In general, however, the data listed in table 1 are believed to be quite reliable indexes of the relative effects of the materials and dosages given upon beneficial species, if used at the season when they are commercially applied to citrus in southern California.

A few general conclusions appear to be warranted. Of primary importance, of course, where protection of natural enemies is desirable, is the choice of materials having rapidly dissipating residues. With persistent-residue insecticides, the reduction of insecticidal concentrations as low

[2] Unpublished data on file at the Citrus Experiment Station.

Table 1.—Toxicity of field-weathered residues of citrus pest control materials to *Aphytis chrysomphali* (Mercet) (A.), *Lindorus lophanthae* (Blaisdell) (L.) and *Metaphycus helvolus* (Compere) (M.).

Material and Dosage	Hours of Continued Exposure Required for 50 Per Cent Kill After Residue Weathering Period of—														
	1 Day			1 Week			1 Month			3 Months			5 Months		
	A.	L.	M.	A.	L.	M.	A.	L.	M.	A.	L.	M.	A.	L.	M.
DDT															
2 lb. (technical) +kerosene, 2.9 gal., +xylene, 1 pt., +blood albumin spreader, 4 oz., per 100 gal. water	3	8	2	4	16	3	5	34	13	23	85	20	37	>100	86
1.5 lb. (50% w.p.)[1] +kerosene, 1.5 gal., per 100 gal. water	3	14	3	5	20	4	9	>100	10	41		96	98		>100
8 lb. (50% w.p.) per acre as mist-concentrate[2]	4	28	3	6	36	7	7	36	12	29	>100	66	>100		>100
1.5 lb. (50% w.p.) per 100 gal. water	4	11	3	6	15	4	31	38	19	>100	>100	>100			
Parathion															
3 lb. (25% w.p.) per 100 gal. water	0.5	11	0.5	0.5	15	1	4	>100	13	12		19	>100		>100
1.5 lb. (25% w.p.) per 100 gal. water	0.5	23	0.5	1	>100	1	4		19	>100		>100			
8 lb. (25% w.p.) per acre as mist-concentrate	0.5	18	0.5	2	>100	6	12		26	>100		>100			
Lime-sulfur solution															
5 gal. per 100 gal. water	14	>100	16	18		20	21		25	74		41	>100		>100
TDE															
2 lb. (50% w.p.) per 100 gal. water	6	>100	12	15		28	33		26	>100		>100			
EPN[3]															
2 lb. (25% w.p.) per 100 gal. water	2	>100	1	3		10	73		>100	98		>100			
Sulfur															
1 lb. sulfur dust (325 mesh) per tree	11	>100	14	18		27	22		33	73		66	>100		>100
4 lb. wettable sulfur (325 mesh) per 100 gal. water	16	69	13	28	>100	17	43		26	>100		>100			
Chlordane															
5 lb. (40% w.p.) per 100 gal. water	6	51	8	33	>100	35	40		>100	>100					
1 lb. dust (5% chlordane) per tree	18	67	24	94	102	>100	>100								
Dieldrin															
2 lb. (25% w.p.) per acre as mist-concentrate	4	94	7	23	>100	78	91		>100	>100					
Aldrin															
4 lb. (12.5% w.p.) per acre as mist-concentrate	10	62	16	34	>100	47	>100		>100						
Dinitro compounds															
1 lb. DN dust[4] (1.5% dust) per tree	0.5	6	3	9	>100	>100	61								
1 lb. DN[5] (20% w.p.) per 100 gal. water	>100	>100	>100	101			>100								
BHC															
1 lb. (0.75% gamma dust) per tree	2	>100	11	30		>100	97								
Oil															
2 gal. (heavy-medium) per 100 gal. water	10	69	25	32	>100	>100	>100								
2 gal. (light-medium, containing 0.05% rotenone) per 100 gal. water	8	74	34	>100	>100	>100									
TEPP															
0.5 pt. (40% solution) per 100 gal. water	2	>100	19	>100		>100									
Nicotine sulphate solution															
0.75 pt. (40% nicotine solution) +casein spreader, 0.25 lb., per 100 gal. water	12	>100	>100	>100											
Pyrophyllite															
1 lb. dust per tree	15	52	>100	100	102	103									
3 lb. per 100 gal. water	>100	>100	>100												
Sabadilla															
1 gal. (0.5% alkaloids) + sugar, 4 lb., per acre as mist-concentrate	16	>100	>100	>100											
Tartar emetic															
2 lb., +sugar, 2 lb., per acre as mist-concentrate	20	>100	>100	>100											
Bis (*p*-chlorophenoxy) methane[6]															
1.5 lb. (40% w.p.) per 100 gal. water	21	>100	>100	>100											
Potassium-ammonium seleno-sulfide 30%[7]															
1 pt. per 100 gal. water	64	>100	>100	>100											

[1] w.p. = wettable powder.
[2] Air-carried spray, using 100 gal. water per acre.
[3] EPN-300, a proprietary product containing 0-ethyl 0-*p*-nitrophenyl benzenethiophosphonate, 25%.
[4] DN-Dust D8, a proprietary product containing 4,6-dinitro-*ortho*-cyclohexylphenol, dicyclohexylamine salt, 1.5%.
[5] DN-111, a proprietary product containing 4,6-dinitro-*ortho*-cyclohexylphenol, dicyclohexylamine salt, 20%.
[6] Neotran.
[7] Selocide.

Table 1 (continued)

Material and Dosage	Hours of Continued Exposure Required for 50 Per Cent Kill After Residue Weathering Period of—														
	1 Day			1 Week			1 Month			3 Months			5 Months		
	A.	L.	M.	A.	L.	M.	A.	L.	M.	A.	L.	M.	A.	L.	M.
Cryolite 3 lb. (95% natural cryolite) per 100 gal. water	99	>100	24	>100		>100									
Hydrated lime 30 lb. per 100 gal. water	>100	>100	>100												
Bordeaux mixture 12 lb. (6 lb. copper sulphate +6 lb. hydrated lime) per 100 gal. water	>100	>100	>100												
Zinc sulphate 4 lb.+soda ash, 2 lb., per 100 gal. water	>100	>100	>100												
P-chlorophenyl *P*-chlorobenzene-sulphonate[a] 1.5 lb. (50% w.p.) per 100 gal. water	>100	>100	>100												
Aramite 3 lb. (15% w.p.) per 100 gal. water	>100	>100	>100												
Zinc oxide 1 lb. per 100 gal. water	>100	>100	>100												

[a] Ovotran.

as is consistent with adequate control serves the same purpose, in that toxicity retention periods are cut to a degree whereby reservoirs of protected stages of beneficial insects are often preserved. Field experience has shown that this type of pest control management is often justifiable. Multiple applications at even very light dosages have been shown to extend dangerously periods of residual toxicity to beneficial species (DeBach 1946). The generally increased toxicity of dusts over spray applications suggests the avoidance of dust applications where sprays may be substituted.

SUMMARY.—New persistent-residue citrus pest control materials, by destroying natural enemies, have caused increases of pests formerly held under biological control, and have caused the rapid flareback of treated pests following initial control. Tests were made to determine the comparative effect upon three species of entomophagous insects of 35 pest control formulations currently used commercially on California citrus. Field-treated citrus leaves were brought to the laboratory for toxicity bioassay following standard periods of field weathering of residues. One coccinellid, *Lindorus lophanthae* (Blaisdell), and two parasitic Hymenoptera, *Aphytis chrysomphali* (Mercet) and *Metaphycus helvolus* (Comp.), were used as insect test species. Test methods are described.

The materials most deleterious to the beneficial insects tested were DDT, parathion, lime-sulfur, TDE, EPN, and sulfur, named in decreasing order of toxicity. Aramite and *para*-chlorophenyl *para*-chlorobenzene sulphonate were practically nontoxic. Very little selectivity of the chemicals to the test species was shown, other than that expected on the basis of their comparative size and vigor. Under arid conditions, dusts were more toxic to the test species than were sprays of the same materials.

LITERATURE CITED

Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. JOUR. ECON. ENT. **18**(4): 265–7.

Bartlett, Blair R. 1951. The action of certain "inert" dust materials on parasitic Hymenoptera. JOUR. ECON. ENT. **44**(6): 891–6.

DeBach, Paul. 1946. An insecticidal check method for measuring the efficacy of entomophagous insects. JOUR. ECON. ENT. **39**(6): 695–7.

DeBach, Paul and Blair Bartlett. 1951. Effects of insecticides on biological control of insect pests of citrus. JOUR. ECON. ENT. **44**(3): 372–83.

Effect of Insecticides on the Metabolism and Motility of Mammalian Spermatozoa[1]

STANLEY D. BECK, *Department of Entomology, University of Wisconsin*[2]

One of the major current problems in economic entomology is the question of the toxicity of insecticides to the higher forms of life, particularly man. Although a fair body of knowledge has been accumulated on the acute and chronic toxicity of certain insecticides to laboratory animals, there is now no known means of transposing such knowledge into terms directly applicable to human health hazards. In the case of the phosphate insecticides an exception is found, for this group of compounds appears to have its primary biochemical activity as anticholinesterases. The effects of phosphate insecticides on blood cholinesterase can be studied in man as well as in lower animals, since the organism need not be sacrificed or endangered during the course of the investigation. As a result of blood cholinesterase studies on man and animals, we have more direct information about the human health hazard involved in the use of parathion and other phosphates than for any other insecticides.

The use of blood is limited, however, and there is a great need for information concerning the effects of insecticides on the essential biochemical processes in other mammalian tissues and organ systems. As far as possible, the tissues used for such investigations should be obtainable from man as well as the standard laboratory animals. Semen is such a tissue, and in this paper an exploratory study of the use of semen and its contained spermatozoa in insecticidal toxicity investigations is presented.

The use of semen in toxicity investigations has several advantages besides the obviously important advantage of enabling one to use man as an experimental object: 1) Semen contains but one cell type, which can be separated from its plasma undamaged. 2) The cells are nonreproducing and apparently autonomous. 3) Spermatozoa have little cell reserve, and nearly all nutritive materials must be assimilated from the surrounding medium. 4) Spermatozoa are highly permeable. And 5) Fertility and motility as well as metabolism may be investigated (Mann 1949).

METHODS AND MATERIAL.—In the experimental work reported here ejaculated semen of the domestic boar was used. Boar ejaculates were collected with the aid of an artificial vagina and were used experimentally immediately after collection.

In most experiments the spermatozoa were removed from the seminal plasma by repeated centrifugation in saline and were suspended in calcium-free Krebs-Ringer saline (Lardy & Phillips 1943; Umbreit *et al.* 1949) to which 0.02 M glucose has been added. In the final dilution of the cell suspension, sufficient saline was added to give a cell density of from 5×10^8 to 1×10^9 cells per milliliter as determined by the use of a standard hemocytometer. When used in metabolism studies it was found that spermatozoa suspensions of this density range yielded results which were linear in respect to both time and cell count, within the time of the experiment.

In experiments in which respiration of boar spermatozoa was followed, Krebs-Ringer phosphate saline containing 0.02 M glucose and no calcium was used at pH 7.25. Glycolysis of boar spermatozoa was followed in Krebs-Ringer bicarbonate saline (free from calcium) at pH 7.40 to which 0.02 M glucose had been added. When suspended in saline containing no utilizable substrate, washed boar spermatozoa showed very low rates of endogenous respiration and glycolysis and rapid loss of motility. Glucose greatly improved respiration, glycolysis, and motility. Pyruvate and succinate improved respiration markedly, but had little effect on motility and, of course, no effect on glycolysis. Glucose at a final (flask) concentration of 0.02 M was adopted as one of the standard conditions. Determinations of pH optima indicated that the pHs indicated above are approximately optimum.

[1] Approved for publication by the Director of the Wisconsin Agricultural Experiment Station.

[2] The writer is pleased to acknowledge his indebtedness to Professors T. C. Allen, L. E. Casida, and R. D. Shenefelt for useful suggestions and for technical assistance in some of the initial experiments. Particular thanks are due to Mr. L. N. Baker for collecting the numerous samples of boar semen used in the course of the study.

Both respiration and glycolysis experiments were conducted by the use of Warburg manometric apparatus using microflasks (7 ml.) containing 1 milliliter of sperm cell suspension in a total volume of 1.6 ml. Gaseous exchange was expressed in terms of ZO_2 and ZCO_2 in respiration and glycolysis experiments respectively. ZO_2 equals microliters of oxygen consumed per 10^8 cells per hour, and ZCO_2 equals microliters of CO_2 evolved per 10^8 cells per hour (Lardy and Phillips 1943). This means of expressing gaseous exchange is similar to the use of Q values, except that it relates activity to cell number rather than dry weight.

Glycolysis in spermatozoa results in the production of lactic acid (Lardy & Phillips 1943). It is well known that production of acid causes a release of carbon dioxide from a carbonate buffer, and in these experiments lactic acid production was followed by measuring the CO_2 evolved from carbonate buffered cell suspensions under anaerobic conditions. Lactic acid analyses demonstrated that with all treatments used CO_2 evolution was directly correlated with lactic acid production.

In respiration and glycolysis experiments cell motility was followed by setting up duplicate treatments in stoppered vials suspended in the Warburg waterbath and from which samples of spermatozoa could be taken without disturbing the respirometer flasks. Motility was estimated visually by examining a small sample of cell suspension under a microscope. The approximate proportion of motile cells was estimated and recorded on a scale of 0 to 10, where 0 indicates no motile cells and 10 indicates all cells motile.

The cells from different semen samples on different days from the same or different boars displayed considerable variation in respect to both motility and metabolism. Although the experimental results were found to be reproducible on a comparative basis, the absolute values obtained were poorly reproducible. For this reason most of the results given below are expressed as a per cent of the values obtained from the untreated or solvent-treated controls. This sample to sample variation has been reported by nearly every worker employing spermatozoa as experimental material.

The insecticidal compounds employed in this study were of the highest available purity; in all cases purity was above 95 per cent. DDT, methoxychlor, BHC, aldrin, parathion, malathon, and TEPP were used. In all cases ethyl alcohol was used as the solvent carrier, and the final concentration of alcohol in the Warburg flasks and motility tubes was one per cent. This concentration of alcohol had no measurable effect on glycolysis; a slight adverse effect was observed on motility; and some inhibition of respiration was observed. An alcohol control was run in every case, however, and the effect of the alcohol was taken into consideration in calculating the experimental results.

RESULTS.—The mean results of four experiments on the effect of several different insecticides on the oxygen consumption of boar spermatozoa are shown in table 1. These data indicate that DDT, aldrin, and malathon had but a minor inhibitory effect on the respiration of boar spermatozoa. Parathion, BHC, and TEPP had an intermediate effect. Only methoxychlor inhibited to a degree approaching that of sodium arsenite. Sodium arsenite is known to be a powerful inhibitor of respiration and was used here as a standard for purposes of comparison.

The effect of the test insecticides on glycolysis in boar spermatozoa is shown in table 2; the data are the means of four experiments. None of the insecticides had an effect comparable to that of iodoacetic acid, which was used as a standard since it is known to be a powerful inhibi-

Table 1.—Effect of certain insecticides on the respiration of washed spermatozoa of the domestic boar.

Time Period (Min.)	Control	Per Cent Inhibition of ZO_2 by Indicated Insecticide at 1×10^{-3} M							
		DDT	Methoxychlor	BHC	Aldrin	Parathion	Malathon	TEPP	Sodium Arsenite
0–60	0	19	40	22	7	19	8	35	82
60–120	0	21	71	44	10	36	10	40	75

Table 2.—Effect of certain insecticides on glycolysis in washed spermatozoa of the domestic boar.

Time Period (Min.)	Control	Per Cent Inhibition of ZCO_2 by Indicated Insecticides at 1×10^{-3} M							
		DDT	Methoxychlor	BHC	Aldrin	Parathion	Malathon	TEPP	Iodoacetic Acid
0–60	0	13	28	36	8	22	23	−10	100
60–120	0	35	49	74	20	27	19	0	100

tor of glycolysis. Methoxychlor and BHC caused inhibition to an intermediate degree; DDT and parathion inhibited slightly; whereas aldrin, malathon, and TEPP had little effect. TEPP stimulated glycolysis during the first 60-minute period but had little or no effect during the second period. This apparent stimulation was not due to hydrolysis of the pyrophosphate molecule, for correction for TEPP blanks failed to eliminate the observed stimulation.

Under the conditions of the present experiments, it was found that the metabolism of boar spermatozoa was predominantly glycolytic. Only about one tenth of the lactic acid produced was oxidized completely, as calculated from the ratio of oxygen consumed to lactic acid produced. Methoxychlor caused even less than one tenth of the lactic acid to be oxidized; the other insecticides had only minor effects. The predominance of glycolysis in spermatozoan metabolism has been reported by several workers (Lardy & Phillips 1941; MacLeod 1941; Mann 1949), although at least some components of the Krebs respiratory cycle are known to be present (MacLeod 1943; Mann 1949).

As shown by the data in table 3, the insecticides tested had a pronounced effect on the motility of boar spermatozoa. Although having a slighter effect than the other compounds tested, DDT had a constant and reproducible inhibiting effect on motility in all experiments run. Therefore the small inhibiting effect shown for DDT in table 3 is considered to be significant. It might be noted here that although in the experiment shown in table 3 motility in the control was good for the two-hour period of the experiment, this was not always the case. In many experiments motility of the control cells dropped rapidly with time, to reach zero in about two hours. In every case, however, the spermatozoa suspensions treated with insecticides showed a much more rapid loss of motility than did the controls.

The data presented in tables 1, 2, and 3 indicate that the insecticides tested had a much greater effect on sperm motility than on either respiration or glycolysis. The inhibition of motility by these compounds was greater than could be accounted for solely on the basis that the compounds inhibited motility through an inhibition of the energy producing respiratory and glycolytic cycles. Unfortunately, almost nothing is known about the motile mechanisms of spermatozoa or of any flagellated cell. The sperm cell is made up with three distinct anatomical (and biochemical) regions: the *head*, which is composed of the cell nucleus accompanied by little or no cytoplasm; the *middle piece*, which is smaller than the head and appears to be the seat of the cell's energetic metabolism; and the terminal *tail* or flagellum, which is connected to the middle piece and is the organ of motility. It is presumed that the contrac-

Table 3.—Effect of certain insecticides on the motility of washed spermatozoa of the domestic boar (all at 1×10^{-3} M).

Time (Min.)	Control	Motility Based on an Arbitrary Scale of 10 (All Motile) to 0 (All Non-Motile)								
		DDT	Methoxychlor	BHC	Aldrin	Parathion	Malathon	TEPP	Na Arsenite	Iodoacetic Acid
0	8	8	8	8	8	8	8	8	8	8
60	7	6	1	3	2	2	3	0	4	1
120	7	5	0	1	1	1	1	0	0	0

tile tail derives its energy from the biochemical activity in the middle piece, but the mechanism of neither the energy transfer nor the energy utilization in flagellar contraction is known. The head and middle piece are invested by a thin lipoid sheath. Since spermatozoa carry practically no nutritive reserves, they must derive nearly all of their energy from the surrounding medium. Toward that end, the lipoid cell membrane of the head and middle piece is apparently permeable not only to metabolizable substrates passing into the cell, but also to coenzymes and metabolic end products leaving the cell.

If a biologically active foreign substance, such as one of the insecticides under discussion, were added to a suspension of spermatozoa, it might inhibit cell motility by any of at least three general mechanisms. First, it might inhibit by combining with enzymes essential to energetic metabolism, thus depriving the cells of a source of energy for motility. In this case there would be a direct correlation between the degree of metabolic inhibition and the degree of motile inhibition; the data obtained in these experiments show no such correlation. Second, the foreign compound might inhibit motility by combining with some essential enzyme or intermediate involved in the motile mechanism itself; this type of inhibition should not affect energetic metabolism until the accumulation of metabolic end products began to inhibit. If this type of inhibition were the case in the present instance, spermatozoa in which motility had been stopped by an insecticide in the absence of a metabolizable substrate should show a near normal rate of metabolism upon the addition of a suitable substrate (glucose, *i.e.*,) but such was found not to be the case (Table 4). The third possible inhibitory mechanism is one in which the foreign compound combines with the cell surfaces to prevent the free exchange of material between the cell and the surrounding medium. In this case enzymes and intermediates escaping before the cell membranes were made impermeable by the foreign compound would continue to function normally in the surrounding medium. The degree to which metabolism would be inhibited would depend on how fast and how powerfully the foreign substance inhibited cell permeability. Spermatozoa in which motility had been completely inhibited by an insecticide in the absence of a metabolizable substrate should show no appreciable recovery upon the introduction of a utilizable substrate such as glucose. That such was the case in the present study is shown by the data presented in table 4.

Although demonstrated only in the case of DDT, it is postulated that the insecticides tested affected an inhibition of spermatozoan motility principally by altering the permeability of the lipoid cell membrane. With the exception of TEPP, all of the insecticides used partition heavily in favor of the oil at an oil-water interface. Although the insecticides were used at a concentration of 0.001 M in the Warburg flasks, all except TEPP formed either a suspension or emulsion because of their low water solubility. With the excess of insecticide present, the aqueous phase (saline) would tend to remain saturated, and the insecticide in solution would accumulate rapidly in the lipoidal phase (cell membrane). The resulting alteration of cell permeability would not necessarily be related to particular chemical groupings in the foreign compound, but would more likely be related to the physical properties such as water and lipoid solubilities, according to Ferguson's Principle (Ferguson 1939). The insecticides used in this study were of approximately the same molecular weight (290–365); all (ex-

Table 4.—The effect of glucose on DDT inhibition of metabolism and motility of washed spermatozoa of the domestic boar. (Initial motility = 8).

Time Period (Min.)	Control						DDT (1×10^{-3} M)					
	No Glucose		Glucose from 0 Time		Glucose from 60 Min.		No Glucose		Glucose from 0 Time		Glucose from 60 Min.	
	CO_2/hr. (mm^3)	mot.[1]	CO_2/hr. (mm^3)	mot.[1]	CO_2/hr. (mm^3)	mot.[1]	CO_2/hr. (mm^3)	mot.[1]	CO_2/hr. (mm^3)	mot.[1]	CO_2/hr. (mm^3)	mot.[1]
0–60	31	1	122	8	29	0	28	0	95	1	20	0
60–120	20	—	95	—	69	—	13	—	92	—	13	—
120–180	9	0	95	6	91	5	13	0	49	0	13	0

[1] Motility figures are for the end of the indicated time period.

cept TEPP) are relatively insoluble in water but quite soluble in oils; all had approximately the same effect on the motility of boar spermatozoa. The effect of DDT on motility was slower than was the case with the other insecticides, and this may have been because of its extreme water insolubility (0.0002 ppm). The postulated inhibition of cell permeability may not be the only effect of the insecticides on spermatozoa, and some of the compounds (particularly TEPP) may affect the cells through different mechanisms.

In this exploratory study no attempt was made to study fertility of treated spermatozoa, and in view of the nonspecific inhibition of motility observed, it is unlikely that fertility tests would yield any useful information. The motility and fertility of spermatozoa produced by treated animals might be of interest.

SUMMARY.—1. Of the insecticides tested (DDT, methoxychlor, BHC, aldrin, parathion, malathon, and TEPP) only methoxychlor had an appreciable inhibitory effect on the oxygen consumption of washed ejaculated spermatozoa of the domestic boar.

2. With the exception of BHC, none of the tested insecticides had more than a weak inhibitory effect on glycolysis of boar spermatozoa.

3. All the insecticides tested had a distinct inhibitory effect on the motility of boar spermatozoa.

4. It was postulated that the insecticides inhibited motility through their altering the permeability of the cell membrane.

LITERATURE CITED

Ferguson, J. 1939. The use of chemical potentials as indices of toxicity. Proc. Roy. Ent. Soc. **B127**: 387.

Lardy, H. A. and P. H. Phillips. 1941. The effect of certain inhibitors and activators on sperm metabolism. Jour. Biol. Chem. **138**: 195–202.

Lardy, H. A. and P. H. Phillips. 1941a. The interrelation of oxidative and glycolytic processes as sources of energy for bull spermatozoa. Amer. Jour. Physiol. **133**: 602–9.

Lardy, H. A. and P. H. Phillips. 1943. Effect of pH and certain electrolytes on the metabolism of ejaculated spermatozoa. Amer. Jour. Physiol. **138**: 741–6.

MacLeod, J. 1941. The metabolism of human spermatozoa. Amer. Jour. Physiol. **132**: 193–201.

MacLeod, J. 1943. The role of oxygen in the metabolism and motility of human spermatozoa. Amer. Jour. Physiol. **139**: 512–8.

MacLeod, J. 1943a. The physiology of mammalian semen. Ann. Rev. Physiol. **5**: 399–412.

Mann, T. 1949. Metabolism of semen. Adv. Enz. **9**: 329–90.

Umbreit, W. W., R. H. Burris and J. F. Stauffer. 1949. "Manometric Methods in Tissue Metabolism." Burgess Publ. Co., Minneapolis.

Corn Earworm Investigations in Florida[1]

N. C. HAYSLIP, E. G. KELSHEIMER, W. H. THAMES, JR. and J. W. WILSON, Entomologists,
Florida Agricultural Experiment Stations, Ft. Pierce, Bradenton, Belle Glade and Sanford, Florida, Respectively

The first commercial production of sweet corn in Florida was reported in the 1947–48 season. Scruggs (1952) reported that Florida produced 33,500 acres of green corn during the 1951–52 season and that the crop was valued at $8,955,000. The establishment of sweet corn as one of the major crops produced in Florida is attributed largely to successful control of insects with the newer insecticides.

The use of 5 to 10 per cent DDT dust, applied with airplanes and high-clearance power dusters every one to three days during the silking period, has produced a high percentage of corn earworm, *Heliothis armigera* (Hbn.), free ears in many of the commercial sweet corn plantings. Other plantings, however, have suffered very serious damage due to corn earworms despite the intensive use of DDT dust for their control. These failures to control corn earworms called attention to the effect of population levels upon the effectiveness of DDT dust. Corn earworm egg deposition was noted to be light during the fall, winter and early spring in most locations. The number of eggs increased greatly in the late spring; it was in these heavily infested fields that dusts were not commercially effective.

[1] Florida Agricultural Experiment Station Journal Series, No. 158.

In an effort to find a more effective and economical control for corn earworms, spray treatments were investigated in the spring of 1948, and these studies have continued since that time. A coordinated research program was started in 1951 in order to allow for a more thorough investigation of the major phases of insecticide treatments. Results of these investigations were published (Wilson—1952, Thames—1952, Hayslip—1952, Wilson *et al.*—1952) and the program was continued in the spring of 1952. A report of the 1952 investigations is made below. Each author, in addition to developing his special phase of the work, tested a "Standard" and a "Special" DDT-oil formulation and each included a DDT dust treatment.

AN EVALUATION OF INSECTICIDES (BRADENTON).—A planting of FM Cross sweet corn was made on February 18, 1952, in rows 54 inches apart. Each plot consisted of a row 50 feet in length and each treatment was replicated four times.

The corn was sprayed at intervals, starting March 6, with 2 quarts of 25 per cent DDT emulsion to 100 gallons of water for the control of budworms, and spraying ceased when the corn was in full tassel. This spraying was done with a high-clearance power sprayer.

The corn earworm sprays were applied with a 4-gallon knapsack sprayer equipped with an 8002 *Teejet* nozzle, at pressures of approximately 60 pounds per square inch. Constant agitation of the spray materials was maintained while the spray was being directed toward the silks. The operator sprayed on both sides of the row. The dust was applied with a hand rotary duster.

A list of treatments is included in table 1. Ten DDT dust applications were made at 2-day intervals, beginning when the first silks appeared and discontinuing when the silks were dry. The "Special" DDT spray formulation was applied 9 times at 2-day intervals, and the "Standard" DDT spray formulation was applied 7 times, with the first two treatments 2 days apart and the balance at 3-day intervals. These DDT formulations were first applied 2 days after the first silks appeared. All other insecticidal formulations were applied 10 times, with the first application when the first silks appeared and the last when the silks were dry.

Discussion of results.—The corn earworm infestation was heavy and uniform. Some infested ears contained as high as 8 third instar larvae. Cool weather delayed maturity of the corn, necessitating more sprays than ordinarily would be required. Mineral oil produced a yellowing of the

Table 1.—An evaluation of insecticides for the control of corn earworm.

TREATMENT	FORMULATION	RATE PER ACRE		PER CENT WORM-FREE EARS	RANK[7]
		Formulation	Diluted Spray		
1. Check	—		—	2.5	6
2. DDT	5% dust	35 lbs.	—	94.0	1
3. DDT (Special)[1]	25% em[3]	4 qts.	50	96.0	1
4. DDT (Standard)[2]	25% em	4 qts.	50	73.0	3
5. Metacide	50% em	12 oz.	100	51.0	4
6. Parathion	25% em	1 qt.	100	65.5	3
7. Parathion	15% W[4]	2 lbs.	100	52.0	4
8. Endrin	— em[5]	1 qt.	100	28.0	5
9. Dieldrin	— em[6]	1 qt.	100	65.5	3
10. DDT	25% em	2 qts.	100	94.5	1
11. DDT	34% em	1 qt.	100	85.5	2
12. Methoxychlor	25% em	2 qts.	100	35.5	5
13. Heptachlor	25% em	2 qts.	100	59.0	3
14. Chlordane	48% em	1 qt.	100	17.5	6
15. Rhothane	25% em	2 qts.	100	78.0	2
16. Malathon	25% em	1 qt.	100	69.5	3

[1] Special DDT+oil combination is: 4 qts. 25% DDT em, containing 15% emulsifier "B" and 60% Xylene+2.5 gal. oil+46.5 gal. H_2O.
[2] Standard DDT+oil combination is: 4 qts. 25% DDT em, containing 5% Triton X-155 and 70% Xylene+2.5 gal. oil+46.5 gal. H_2O.
[3] em=emulsifiable concentrate.
[4] W=wettable powder.
[5] 0.5 lb. active ingredient per 1 gallon.
[6] 1.5 lbs. active ingredient per 1 gallon.
[7] Based upon analyzed data of No. of worm-free ears at odds of 19:1. No. 1=best, No. 6=poorest.

corn plants but it did not decrease the yield, so yield data are not included. Measurements of unfilled tips were made on 20 ears from each plot but no difference was found.

The results of the earworm treatments are given in table 1. The best treatments were DDT dust, DDT 25 per cent emulsion, 2 quarts to 100 gallons of water, and the DDT "Special" oil treatment. The poorest treatments were the check and chlordane, which fell in the same group.

The corn leaf aphid, *Aphis maidis* Fitch, was unusually abundant in the tips of the ears. No aphid infestations were noted on ears of sweet corn from plots treated with 5 per cent DDT dust, Metacide, parathion, endrin, dieldrin, 34 per cent DDT, heptachlor, chlordane, or malathon. Ears of corn on plots treated with 25 per cent DDT emulsion and DDT emulsion+mineral oil were as heavily infested with aphids in the tips of the ears, as were the check plots.

DDT SPRAY FORMULATIONS (FT. PIERCE).—A planting of Ioana sweet corn was made on March 20, 1952, in rows spaced 42 inches apart. There were 18 treatments and 5 replications. Each plot consisted of two rows 26 feet in length, with a buffer row between plots.

The corn grew very rapidly, producing a dense foliage and numerous suckers. A strong wind and rain caused the suckers to lodge and it was necessary to remove some of them in order to facilitate treatment.

The fall armyworm, *Laphygma frugiperda* (A. and S.), population was moderate; these were controlled by applications of 50 per cent wettable DDT at about weekly intervals until the corn tassels began to appear. Zineb was added to the insecticide spray for the control of Helminthosporium leaf blight. These sprays were applied with a 6-row power sprayer, using 3 nozzles per row, until the corn became too tall. The last fall armyworm and zineb sprays were applied with a boom carried by hand.

The corn earworm sprays were applied with two 2.5 gallon compression-type hand sprayers, equipped with pressure gauges and *Teejet* 9502 flat fan-type nozzles. The operator held the nozzle above the silking zone and directed the spray downward to cover the silks. The nozzle was carried along one side of the row and back the other, giving the equivalent of two nozzles per row. Fifty gallons of spray were applied per acre at pressures of 50 to 60 pounds per square inch. Plot No. 15 (Table 2) was sprayed with a power sprayer at about 100 pounds pressure. Four nozzles per row were directed into the silking zone from slightly above, 2 nozzles on each side of the row. *Teejet* 6502 tips were used. The DDT dust treatment was made with a rotary-type hand duster, directing the dust to the silks from each side of the rows.

Data obtained included an estimate of the degree of yellowing of the corn plants, the average number of eggs per silk on May 15, per cent worm-free ears, total weight of corn (unhusked), weight of corn with a husked ear length of 6 inches and over, and average weight of ears 6 inches and over in length. Notes were taken on tip development.

Discussion of results.—As indicated by the untreated check plots (Table 2), showing 100 per cent wormy ears, this trial was conducted during a very severe corn earworm infestation. The egg count on May 15 showed an average of about 2.5 eggs per silk. The heavy growth of leaves and suckers reduced the amount of spray coverage on the silks.

It will be noted in table 2 that there was considerable yellowing of the corn plants where Blandol was used. As was expected, Plot No. 15, which received two more applications than the other spray treatments and which was applied with a power sprayer, had the highest average score for degree of yellowing. Yellowing of the corn was caused by the mineral oil.

There were very small differences between treatments in ear size and yields but these were not significant. Low yield trends were obtained in treatments numbered 5 and 15. No explanation is offered at this time for the low yield trend in treatment No. 5, in which the variable was 7.5 per cent emulsifier "B" rather than 15 per cent. Treatment 15 received two more spray applications than any of the other treatments and it is possible that the lower yield trend was due to these extra applications or to the more complete plant coverage in these plots obtained with the power sprayer. These two treatments having the lower yields also contained smaller ears of corn.

Inspection of ear tips indicated that some of the spray treatments had a slight effect on tip development. The tip fill,

Table 2.—Description of DDT spray formulations and their effect on corn earworm control and yellowing of plants.

PLOT NO.	SOLVENT	EMULSIFIER	PER CENT TECH. DDT	QTS. DDT EMUL. PER ACRE	AMOUNT OF YELLOWING[3]	PER CENT WORM-FREE EARS
1[1]	70% Xylene	5% Triton X-155[6]	25	4	3.40	57
2	60% Xylene	15% Em "B"[7]	25	4	4.60	61
3	60% Xylene	15% Em "B"	25	3	4.40	64
4	72.5% Xylene	15% Em "B"	12.5	4	3.80	41
5	67.5% Xylene	7.5% Em "B"	25	4	4.40	66
6	85% Xylene	15% Em "B"	None	4	3.20	4
7	70% Xylene[4]	5% Triton X-155	25	4	0.80	39
8	60% Xylene[4]	15% Em "B"	25	4	0.60	30
9	70% Xylene[4]	5% Triton X-155	25	4	0.20	35
10	70% Xylene	5% Triton X-177[6]	25	4	3.60	65
11	69% Xylene	6% Atlas G2090[8]	25	4	4.80	62
12	69% Xylene	6% Atlas G1087[8]	25	4	4.20	71
13	60% Velsicol AR50[5]	15% Em "B"	25	4	4.20	71
14	60% Velsicol AR50G[5]	15% Em "B"	25	4	4.20	72
15[2]	60% Xylene	15% Em "B"	25	4	6.00	89
16	6 pounds of 50% wettable DDT per acre in 50 gallons water				0.00	14
17	10% DDT dust—every other day—35 pounds per acre				0.40	27
18	Check, not treated	—	—	—	0.60	0
LSD—19–1						10

[1] Standard formulation tested also at Sanford, Bradenton and Belle Glade.
[2] Special formulation tested at above locations. This plot received 6 power sprayer applications at 2-day intervals, beginning 2 days after the first silks appeared. All other sprays were treated with hand sprayers, 4 times at 3-day intervals beginning 2 days after first silks appeared. All spray plots received 50 gallons of diluted spray per acre.
[3] 0=deep green; 10=yellow. Figures indicate the average score for the 5 replications.
[4] Blandol oil, 2.5 gallons per acre, used in all plots except Nos. 7, 8, and 9. Glycerin, 0.5 gallon per acre used in No. 9.
[5] Velsicol Corporation. [6] Rohm and Haas. [7] L. Sonneborn Sons, Inc. [8] Atlas Powder Co.

however, was satisfactory in most of the treatments. Accurate counts or measurements of tips were not possible due to the heavy earworm damage in many treatments.

The effectiveness of each treatment was measured by examining 20 ears per plot, or 100 ears per treatment. The results based upon worm-free ears are recorded in table 2. The following are some of the more important conclusions:

1. Six power sprayer applications at 2-day intervals gave better control than four hand sprayer treatments at 3-day intervals, using the same formulation and rate of application.

2. Four quarts per acre per treatment of a 12.5 per cent DDT emulsion gave fewer worm-free ears than an equal amount of 25 per cent DDT emulsion, both used with 2.5 gallons of mineral oil per acre and diluted with water to make 50 gallons of spray.

3. Blandol with xylene and emulsifier "B," but without DDT, gave only 4 per cent worm-free ears, indicating that these materials as applied had little insecticidal qualities.

4. Six pounds of 50 per cent wettable DDT per acre per treatment applied in 50 gallons of water was inferior to sprays with DDT-oil emulsion, DDT emulsion without oil, and 10 per cent DDT dust.

5. Of the emulsifiers tested, Triton X-155 gave the lowest (57 per cent) and Atlas G1087 gave the highest (71 per cent) worm-free ears.

6. The use of mineral oil with the DDT emulsion resulted in a larger percentage of worm-free ears than where the DDT emulsion was used alone.

7. DDT emulsion sprays without oil gave only slightly more worm-free ears than 10 per cent DDT dust.

8. Three quarts of 25 per cent DDT emulsion with mineral oil gave control equal to 4 quarts with mineral oil in this test.

9. The solvents, Velsicol AR50 and AR50G gave 10 and 11 per cent more worm-free ears respectively than xylene.

TIME AND NUMBER OF DDT APPLICATIONS (BELLE GLADE).—The purpose of this trial was to determine the limit beyond which an increase in the number of applications of insecticide, or an increase in the protection period by lengthening intervals between applications, gave no increase in per cent worm-free ears.

Method.—Ioana variety sweet corn was

Table 3.—Corn earworm control. Effect of varying time, interval, and number of applications of insecticides on the per cent of worm-free ears. Average per cent worm-free ears of 5 replicates and the per cent ears in silk at first application are shown for each treatment. Variety Ioana, planted at Belle Glade, Florida on March 14, 1952. First silks appeared on May 11.

Treatment[1,2,3]	No. of Applications	Interval between Applications (Hours)	Per Cent Ears in Silk at First Application	Per Cent Worm-Free Ears
1	6	48	0	92.0
2	5	48	0	89.6
3	4	48	0	54.4
4	6	Irregular	0	80.0
5	6	48	35	90.4
6	5	48	35	92.0
7	4	48	35	71.2
8	4	48	—	85.6
9	6	72	0	83.2
10	5	72	0	88.0
11	4	72	0	88.0
12	3	72	0	55.2
13	5	72	12	92.0
14	4	72	12	87.2
15	3	72	12	65.6
16	4	96	0	65.6
17	3	96	0	58.4
18	4	96	12	72.8
19	3	96	12	72.0
20	6	48	0	71.6
21	5	48	0	48.8
22	4	48	0	26.4
23	6	48	35	68.0
24	4	48	35	55.2
25	8	24	0	16.0
26	8	24	35	72.0
27	7	48	0	52.0
28	7	48	35	38.4
29	5	48	12	73.6
30	Check	—	—	00.0
LSD at 19:1				16.1
LSD at 99:1				21.3

[1] Treatments 1 through 19, and 29 received 4 quarts of 25 per cent DDT emulsion and 2.5 gallons of Bandol in water to make 50 gallons.
[2] Treatments 20–24, inclusive, received 4 quarts of 25 per cent DDT emulsion in water to make 50 gallons.
[3] Treatments 25–28, inclusive, received 5 per cent DDT dust at 40 pounds per acre.

planted in rows 36 inches apart and 270 feet long on March 19, 1952 for a randomized block trial of 30 treatments replicated 5 times. Each plot consisted of 4 rows 35 feet long. During the pre-tasseling period weekly applications of 25 per cent DDT emulsion at the rate of 1 quart in 100 gallons of water were made to control a moderate infestation of fall armyworms feeding in the buds.

Treatments.—Treatments 1 to 19 inclusive (Table 3) consisted of applications of a mixture containing 4 quarts of 25 per cent DDT emulsion[2] and 2.5 gallons of oil with water to make 50 gallons. This material was applied at the rate of 50 gallons per acre from a 2.5 gallon compression sprayer with a flat fan spray nozzle at a pressure of about 60 pounds per square inch. Each side of each row was treated. The nozzle was carried 6 to 8 inches above the average height of the top ear. Treatments 20 to 24 inclusive were applied with the same equipment, using the same method as treatments 1 to 19 inclusive. The insecticide mixture was the same except that no mineral oil was used. Treatments 25 to 28 inclusive received 40 pounds per acre of a 5 per cent DDT dust which was applied to each side of each row with a rotary hand duster, directing the dust at the silks of the top ears. Dusts were applied in the early morning when the silks were wet with dew.

Treatment 29 was applied with four nozzles attached to a length of 0.5 inch pipe rigged to resemble a "drop" of a high clearance sprayer. This "drop" was attached to a 4-foot spray boom and a long spray hose and carried over the shoulder of the operator. The pump pressure was 100 pounds per square inch and the insecticide mixture was applied at the rate of 50 gallons per acre with two nozzles to each side of the row. The insecticide consisted of 4 quarts of 25 per cent DDT emulsion,[3] 2.5 gallons of oil and water to make 50 gallons.

In addition to the different materials, the treatments differed in the time of applications with relation to silking stage, the interval between applications, and the number of applications as shown in table 3.

The time at which treatments were started was based on the per cent of plants with ears in silk as determined by

[2] Prepared as follows: Technical DDT, 25 per cent; xylene 70 per cent; and Triton X-155, 5 per cent by weight.
[3] Prepared as follows: Technical DDT, 25 per cent; xylene 60 per cent; Sonneborn's Emulsifier "B," 15 per cent.

the average of five plots in each block. On May 10 no ears were in silk. On May 11 from 1 to 3 per cent were silking, and on May 13 the average in silk was 35 per cent. The variation in per cent of plants with ears in silk from plot to plot by May 13 was considerable. The range was from 18 per cent in one plot to 66 per cent in the most advanced plot. These differences resulted in variations in control obtained for different replicates of the same treatment.

At maturity on May 28 the primary ears were harvested, and 25 ears from each plot were examined to determine the per cent of ears free of corn earworms or their damage. Ears were considered infested if earworms were in the silk channel. The total yield in pounds was recorded for this harvest, and for all ears 6 inches or longer obtained at the second harvest 3 days later. Differences in yield were not significant, and yields are therefore omitted from the table of results.

Discussion of Results.—The variation in per cent worm-free ears between replicates of the same treatments was too great to permit statistical separation of the best treatments. Sixteen per cent is required to show significant difference at the 5 per cent confidence level and 21 per cent at the 1 per cent level. This variation is attributed to the lack of uniformity in silking, and in the height of the top ears which hindered uniform application of the treatments.

The DDT-oil mixtures were superior to DDT emulsion without oil and to DDT dusts at the level of infestation experienced in this trial.

It appears that sweet corn of this variety must be protected for the period beginning the day after the first silks appear through the fourteenth day after silking.

The principal benefit of an increased number of applications was that of extending the period of protection. Similarly an increase in the interval between applications of a treatment had the same effect, provided this interval was not so long as to allow the application to become ineffective.

A higher number of worm-free ears was obtained by delaying the date of the first application until the third or fourth day after silking began in treatments limited to 3 or 4 applications. Compare treatments 3 and 7, 12 and 15, and 17 and 19, as shown in table 3.

The most effective interval between applications will vary with the total number of applications, and with the insecticide formulations used. With four applications of the DDT-oil spray, best control was obtained at the 72-hour interval; with three treatments the best interval was 96 hours. With the 5 per cent DDT dust, 8 applications with 24-hour intervals gave 72 per cent worm-free ears, while 7 with 48-hour intervals gave only 38 per cent worm-free ears. This information indicates that DDT dusts require a shorter interval between treatments than do the DDT-oil sprays.

An analysis of eight treatments from the 1951 and 1952 trials was made. These treatments shown in table 4 were selected because they were almost the same with respect to material applied, interval between applications, and time of starting. The resulting per cent worm-free ears for each similar treatment compares very closely for the 2 years. The F test shows no significant difference between the two seasons. This comparison shows that, under the conditions of the trials, no difference in worm-free ears may be expected with the DDT-oil mixture by increasing the number of applications beyond five.

Table 4.—A comparison of the results of time and number of applications, trials conducted in 1952, with similar treatments applied in 1951.

No. of Applications[1]	Interval between Applications (Hours)	Days After First Silk at First Application	Per Cent Worm-Free Ears		
			1951	1952	Average
6	48	3	96	90.4	93.2
5	48	3	92	92.0	92.0
5	72	3	83	92.0	87.5
4	72	2	87	87.2	87.1
4	48	3	70	71.2	70.7
4	48	5	79	85.6	81.3
3	72	3	70	65.6	69.0
6 in '51 / 7 in '52	48	3	36	37.4	36.7
LSD[2] at 99:1			27	21.3	12.5

[1] All treatments were made with DDT-mineral oil mixture except for the last, in which 5 per cent DDT dust was used.

[2] LSD of average per cent worm-free for the two years is based on analysis of the 8 treatments shown in the table. Interaction between treatment and season was not significant, nor were season differences. LSD for the 1951 and the 1952 results are those from analyses of 48 treatments in the 1951 trial and 30 in the 1952 trial.

METHODS OF APPLYING DDT SPRAYS (SANFORD).—Problems connected with the application of DDT and oil with water as a diluent have been studied during the 1951 and 1952 growing seasons. The factors studied in 1951 included: (1) the amount of water, (2) the kind of nozzles, (3) the number of nozzles per row, and (4) the pump pressure. Results of the 1951 experiments (Wilson 1952) showed that the highest per cent of worm-free ears was produced in plots where the DDT and oil were applied in 81 gallons of water per acre, and where the *Teejet* No. 6503 nozzle was used.

The difference between four and five nozzles to the row, and the differences between 60, 100 and 200 pounds pressure per square inch, were not significant. The factors studied in 1952 included: (1) three formulations of DDT, which were also used by the other three authors at other locations; (2) the comparative effectivness of three flat fan nozzles having different widths of spray coverage; (3) the effect of varying the number and position of the nozzles used; and (4) the most effective amount of water to be used for carrying the DDT and oil.

Methods.—Plots were four rows wide and 40 feet long. All the treatments were applied with a power sprayer equipped with a four-row boom. Treatments were arranged in four groups and randomized within the group with five replicates for each treatment. This arrangement did not provide for a statistical comparison of treatments in the different groups. The first group consisted of the "Special" DDT spray treatment and the "Standard" DDT spray treatment described in the DDT formulations section, 5 per cent DDT dust and a check. The insecticide sprays in this group were applied at the rate of 100 gallons of spray per acre, with four *Teejet* No. 6503 nozzles per row at a pump pressure of 100 pounds per square inch. The DDT dust was applied by a rotary hand duster at an average rate of 39.5 pounds per acre at 48-hour intervals.

In the second group of treatments flat fan nozzles having different angles of spray coverage were the varying factors. Four nozzles per row delivered 100 gallons of spray per acre. In the third group of treatments the position and the number of nozzles per row varied, while the pump pressure was maintained at 100 pounds per square inch. The tractor speed was varied to deliver 100 gallons per acre for each of the treatments. In the fourth group of treatments four Teejet No. 6503 flat fan nozzles per row were used with a pump pressure of 100 pounds per square inch. The speed of the tractor was varied to deliver 65, 100 and 125 gallons of spray per acre.

Treatments in all groups were first applied 2 days after the first silks appeared and four subsequent spray applications were made at 72-hour intervals. All of the spray treatments were applied at the rate of 2 pounds of technical DDT and 2.5 gallons of oil to the acre per application. Methods of taking samples and recording data were similar to those outlined in the formulations section.

Discussion of Results.—An irregularity of silking and a very high earworm population during the silking period made it very difficult to obtain good earworm control. Earworm egg counts, made 4 and 8 days after the first silks appeared, showed 131 and 81 earworm eggs respectively per 100 silks. Another indication of the very high earworm population was that only 6 per cent worm-free ears was harvested from the DDT dust-treated plots and no worm-free ears from the untreated plots. The list of treatments and results are presented in table 5.

The total yield showed no significant differences between any of the treatments in all of the groups. This indicates that there was no adverse effect of the DDT-oil treatments, although at the beginning of harvest the DDT-oil treated plants were noticeably lighter in color than the untreated and dust-treated plants. At 19

Table 5.—Results of corn earworm control tests at Sanford, Florida, 1952.

TREATMENT	PER CENT WORM-FREE EARS	TREATMENT	PER CENT WORM-FREE EARS
Formulations		*Number of Nozzles*	
Check	0	2 No. 11004	50
Special	35	2 No. 8004	52
Standard	47	5 No. 6503	38
5% DDT dust	6	Check	0
LSD (99:1)	14.9	LSD (99:1)	20.07
Type of Nozzle[1]		*Amount of Water per Acre*	
Teejet No. 6503	25	65 gallons	36
Teejet No. 8004	39	100 gallons	35
Teejet No. 11004	31	125 gallons	46
LSD (19:1)	[2]	LSD (19:1)	[2]

[1] First two or three digits in the nozzle number indicate the degree of the spray angle leaving the nozzle at 40 pounds p.s.i., while the last two indicate the orifice size.
[2] Differences not significant.

to 1 odds the "Standard" formulation gave significantly better corn earworm control than the "Special" formulation, but at 99 to 1 odds there was no significant difference between the two treatments.

Differences in per cent worm-free ears harvested from plots treated with the 65, 80 and 110 degree flat fan nozzles were not significant. Differences between two 110 degree nozzles, and two 80 degree nozzles per row were not significant, but these two treatments were significantly better than five 65 degree nozzles. Differences between 65, 100 and 125 gallons of spray per acre were not significant. There was no indication that the DDT-oil treatments had interfered with pollination.

Conclusions.—Results of this series of tests indicate that applications of 2 pounds per acre of technical DDT in an emulsifiable formulation containing 5 per cent Triton X-155 and 70 per cent xylene by weight with 2.5 gallons of Blandol in 65 to 125 gallons of water, with two 80 degree flat fan nozzles per row, will give satisfactory earworm control under most conditions.

SUMMARY.—A large percentage of Florida's sweet corn has been produced during periods when there was a relatively light corn earworm, *Heliothis armigera* (Hbn.), population. DDT dusts have resulted in a high percentage of worm-free ears during these periods. However, a less expensive and more effective corn earworm treatment is needed, especially for heavy insect populations. A coordinated corn earworm research program was initiated in 1951, dividing the responsibility into the following phases: (1) an evaluation of insecticides other than DDT, (2) DDT formulation studies, (3) timing and number of DDT-oil spray treatments, and (4) methods of applying DDT-oil sprays. The spring, 1952, results are reported above.

Variety FM Cross was used for an evaluation of insecticides. Included in the replicated experiment were DDT dust, DDT emulsion, and DDT emulsion-mineral oil, Metacide, parathion, endrin, dieldrin, methoxychlor, heptachlor, Rhothane, and malathon. Hand spraying and dusting equipment were used. The corn earworm population was severe. None of the treatments reduced the yield, nor did they prevent normal pollination. The most effective treatments were 5 per cent DDT dust, 25 per cent DDT emulsion (2 quarts) and 25 per cent DDT emulsion (4 quarts) plus white mineral oil (2.5 gallons). The poorest plots were chlordane and the untreated check.

Variety Ioana was used for the DDT spray formulation studies. All sprays and dust were applied with hand application, except one power sprayer treatment. Three solvents, five emulsifiers, mineral oil, glycerin, wettable powder and dust were evaluated in this experiment. No yield differences and only slight differences in pollination and ear tip fill occurred between treatments, although all oil treatments caused some yellowing of the corn plants. The following results were noted: (1) Six power sprayer treatments were superior to 4 hand-sprayed treatments, using DDT-oil emulsion; (2) 4 quarts per acre of 25 per cent DDT emulsion was superior to the same quantity of 12.5 per cent, both used with mineral oil. Omitting DDT from the solvent-emulsifier-mineral oil formula resulted in very poor control; (3) 6 pounds per acre of 50 per cent wettable DDT was inferior to the DDT-oil emulsion, DDT emulsion and 10 per cent DDT dust; (4) the emulsifier, Atlas G1087, gave the highest (71 per cent) and Triton X-155 gave the lowest (57 per cent) worm-free ears; (5) the addition of mineral oil to the DDT emulsion increased the control; (6) DDT emulsion without mineral oil gave only slightly more worm-free ears than 10 per cent DDT dust; (7) 3 quarts of 25 per cent DDT emulsion per acre with mineral oil gave control equal to 4 quarts with mineral oil; (8) the solvents, Velsicol AR50 and AR50G gave 10 and 11 per cent more worm-free ears respectively than xylene.

Tests conducted with Ioana variety sweet corn for the purpose of determining the number of applications, interval between applications, and time to initiate applications of three formulations of DDT to control the corn earworm showed that, with the level of infestation occurring during the silking period of this trial (May) best control was obtained with five and six applications at intervals of 48 hours of a DDT-mineral oil mixture. It appears that there is a period of about 12 days during which ears must be protected.

Methods of applying DDT sprays were

investigated, using a tractor-drawn 4-row power sprayer and a rotary-type hand duster. Treatments were divided into 4 groups, as follows: (1) formulations; (2) type of nozzles; (3) number of nozzles per row; and (4) the amount of liquid applied to one acre. Yields and pollination of corn were not affected by any of the treat ments. The two DDT-oil spray formulations tested were superior to 5 per cent DDT dust. Differences between plots treated with 65, 80 and 110 degree flat fan nozzles were not significant. Five 65 degree nozzles per row gave poorer control than did two 110 degree or two 80 degree nozzles per row. Differences between 65, 100 and 125 gallons of spray per acre were not significant. This series of tests shows that DDT-mineral oil emulsified with 65 to 125 gallons of water, and applied with two 80 degree flat fan nozzles per row gave the best corn earworm control.

The variation in control obtained at the different locations with DDT dusts is difficult to explain. There is evidence that timing of the treatments may account for these differences. In the timing studies, seven treatments made at 24-hour intervals resulted in 72 per cent worm-free ears when the first application was made when 35 per cent of the corn had silks. Only 16 per cent worm-free ears were obtained when the treatments began before the first silks appeared.[1]

[1] Acknowledgments.—The authors wish to express appreciation to Drs. A. N. Tissot and D. O. Wolfenbarger for reading this manuscript and making many helpful suggestions.

LITERATURE CITED

Hayslip, Norman C. 1952. Corn earworm control-formulations. Fla. Ent. 35(2): 51–6.
Scruggs, Frank H. 1952. Annual fruit and vegetable report, 1951–52 season. Florida State Marketing Bureau. Page 46.
Thames, Walter H., Jr. 1952. Corn earworm control—timing and number of applications. Fla. Ent. 35(2): 47–50.
Wilson, J. W. 1952. Corn earworm control—spraying methods. Fla. Ent. 35(1): 3–9.
Wilson, J. W., Walter H. Thames, Jr., Norman C. Hayslip. (1952). Corn earworm control—summary and recommendations. Fla. Ent. 35(2): 57–61.

The Effect of Certain Microorganisms and Antibiotics on Stored-Grain Insects[1]

EDWARD A. STEINHAUS and C. RITCHIE BELL,[2] *Department of Biological Control, University of California, Berkeley*

The milling industry annually uses millions of bushels of wheat most of which is stored progressively in bins and country elevators, shipped bulk in boxcars to mills, stored in mill elevators, and then processed into flour, feed, and other wheat products. Beginning in the farmer's bins this wheat becomes infested with insects and becomes increasingly contaminated in the country elevators and in shipping; the resulting loss of grain is tremendous and fragments of insects are carried through into the flour or other end products.

Numerous methods and procedures have been devised and used to cope with the problem of insect infestation of wheat and other stored grains. Control of the insects has been instituted through the use of fumigants, insecticides, and improved storage practices. Although successful under certain circumstances, these methods have not afforded the degree and inexpensiveness of control desired by the milling industry. Apparently, an ideal solution to the problem would be the addition of some inexpensive additive to the grain that could be applied by the farmer as he brings his wheat in from the field, and that would thereafter either repel the insects or rapidly kill any that might get into the wheat. It would be desirable that such protection be effective for at least a

PAID PAPER.
[1] This investigation was supported by a generous grant-in-aid from General Mills, Inc., Minneapolis, Minnesota.
[2] The authors gratefully acknowledge the assistance of Nancy S. Scherer and Mariece M. Batey in the technical performance of certain parts of this study.

year. Certain so-called "protectants" have to some extent approached this ideal but apparently they have not solved the problem from the miller's viewpoint. Costs even as low as 2 cents a bushel in the aggregate amount to tremendous costs for large milling industries.

THE SUSCEPTIBILITY OF STORED-GRAIN INSECTS TO MICROORGANISMS.—Inasmuch as the use of chemical poisons has not as yet brought about a solution of the stored-grain insect problem to the satisfaction of the milling industry, a preliminary survey of the possibilities associated with the use of microorganisms pathogenic to the insects has appeared worthwhile. Virtually nothing has been known concerning the use of microorganisms in the possible control of stored-grain insects, making it almost impossible to speculate as to the potentialities involved. Certain factors, such as the general lack of susceptibility of adult beetles to microbial infection and the relative inaccessibility of the larvae of some species inside the grain kernels, do give reason to be pessimistic about achieving marked success along these lines. The fact that several different species of insects are usually involved at any one time also complicates the picture. Nevertheless, a satisfactory conclusion or judgement concerning the possible use of microbial control methods cannot be arrived at until at least some preliminary experimentation has been performed. To accomplish this has been one of the purposes of the investigation being here reported. The second objective was to determine the effect of the oral administration of antibiotics on the intracellular microorganisms occurring in certain species of stored-grain insects, and the accompanying effect these drugs might have on the insects.

For reasons of convenience the present report is divided into two sections, one having to do with the susceptibility of stored-grain insects to microorganisms, the other being concerned with the effect of antibiotics on stored-grain insects.

MATERIALS AND METHODS.—The stored grain with which we were primarily concerned in this investigation was wheat. Accordingly, the following pests of this grain were used in our studies: the granary weevil, *Sitophilus granarius* (Linn.); the rice weevil, *Sitophilus oryza* (Linn.); the lesser grain borer, *Rhizopertha dominica* (Fabr.); the confused flour beetle, *Tribolium confusum* Duv.; and the angoumois grain moth, *Sitotroga cerealella* (Oliv.). All strains of these insects used in the infectivity tests were obtained from local sources of infested grain. Cultures of these insects were maintained in gallon jars one-third full of wheat held at the appropriate temperatures and humidities for each species. Only adult insects were used in the infectivity tests.

No microorganisms specifically and distinctly pathogenic for any of the above-named insects are known. For this reason it was necessary for us to assemble microorganisms known to be pathogenic for other insects or thought to be potential pathogens under certain conditions, and then to test the stored-grain insects for their susceptibility to these pathogens. It might also be mentioned that no viruses are known to be capable of infecting coleopterous insects; most virus infections are limited to Lepidoptera and Hymenoptera. The microorganisms collected and, during the course of this investigation, tested for their pathogenicity to the grain insects are listed in table 1.

The susceptibility tests were run in petri dishes, half-pint cartons, and in one-gallon glass jars, each type of container being partially filled with grain into which the test insects were introduced. Varying concentrations of the test microorganisms were incorporated in the grain either as a dust or by emmersing the grain in an aqueous suspension (with blood albumen added to enhance the spreading qualities) of the microorganisms after which the kernels were quickly dried in the air or in a warm oven. Appropriate controls were used in all tests. Injection of the microorganisms directly into the body cavity of the insects was not done since this form of artificial introduction of an organism is, in our opinion, an inadequate test of the natural susceptibility of an insect to an infectious agent.

RESULTS OF INFECTIVITY TESTS.—In general, none of the infectivity tests revealed any great degree of susceptibility of the stored-grain insects to the test microorganisms, at least under optimum rearing conditions for the insects. The results are tabulated in Tables 2, 3, 4 and 5

Table 1.—The microorganisms used to test the susceptibility of the stored-grain insects studied.

Name of Microorganism	Source (Insect or Collection of)
Bacteria	
Bacillus thuringiensis Berliner (0-3-30)	*Ephestia kühniella* Zeller
Bacillus thuringiensis Berliner (0-3-33)	*Ephestia kühniella* Zeller
Bacillus thuringiensis Berliner (58-1-1)	*Aphomia gularis* (Zeller)
Bacillus thuringiensis Berliner (57-1-1)	*Plodia interpunctella* (Hbn.)
Bacillus thuringiensis Berliner (B-14)	*Peridroma* sp.
B. alvei Cheshire & Cheyne	Nathan R. Smith (No. 686) (originally isolated from *Apis mellifera* Linn.)
B. laterosporus Laubach	Nathan R. Smith (No. 661)
B. subtilis Cohn emend. Prazmowski	Nathan R. Smith (No. 231)
B. cereus Frankland & Frankland	Nathan R. Smith (No. 201)
B. cereus Frankland & Frankland (var. *mycoides* Flügge)	Nathan R. Smith (No. 233)
B. pumilis Bottheil	Nathan R. Smith (No. 236)
B. megaterium De Bary	Nathan R. Smith (No. 234)
B. popilliae Dutky	*Popillia japonica* Newm. (USDA)
B. popilliae Dutky mixed with *B. lentimorbus* Dutky	*Popillia japonica* Newm. ("Japonex")[1]
Serratia marcescens Bizio	*Dacus dorsalis* Hendel
Serratia marcescens Bizio	Robert S. Breed (18-1-3)
Serratia marcescens Bizio	Robert S. Breed (6-42)
Sarcina lutea Schroeter	Dept. of Bact., Univ. Calif.
Pseudomonas sp.	*Pyrausta nubilalis* (Hbn.)
Fungi	
Beauveria bassiana Bals.	American Type Culture Collection (No. 9835)
B. bassiana Bals.	*Crambus bonifatellus* (Hulst)
B. bassiana Bals.	*Pyrausta nubilalis* (Hbn.)
B. globulifera (Speg.)	*Euphydryas chalcedona* (Dbldy. & Hew.)
Metarrhizium sp. (probably *M. anisopliae* (Metch.)	*Oryctes rhinoceros* Linn.
Metarrhizium sp.	*Polyphylla barbata* Cozier
Protozoa	
Nosema sp.	Unidentified cutworm
Plistophora sp.	Unidentified cutworm
Perezia pyraustae Paillot	*Pyrausta nubilalis* (Hbn.)

[1] The "Japonex" used in these experiments was obtained from Fairfax Biological Laboratory through the courtesy of Mr. H. A. Chittick.

and, as they pertain to each of the insect species tested, are here summarized briefly.

Sitophilus oryza.—The rice weevil appeared to be susceptible in varying degrees to four species of the microorganisms tested: *Bacillus thuringiensis* (three strains), *Bacillus cereus*, *Serratia marcescens* (two strains), and *Beauveria bassiana*. Only *B. thuringiensis* appeared to exhibit the consistency and vigor of infection indicative of a true pathogen.

In the experiments using *Bacillus thuringiensis* as the test organism, the bacteria were applied either by immersing the grain in an aqueous suspension of the spores, followed by drying, or by incorporating dry spore dust with the grain. The grain was placed in petri dishes and the weevils (5 to 20) added. It is presumed that the spores are ingested by the adult insects while eating through the outer coat of the seed. The weevils died, apparently of infection, from as early as three days to as long as 24 days after exposure. Most of the deaths took place within 14 to 21 days.

External evidences of infection with *Bacillus thuringiensis* were slight, a gradual lessening of mobility being about the only significant symptom observed.

Histological sections of the diseased weevils showed the presence of *Bacillus thuringiensis* (as confirmed by microscopic and cultural examinations) in the body cavity of the insects. The vegetative cells of the bacillus occurred freely in the hemocoele of the insect as well as congregated in masses at the surfaces of various tissues (fat, muscle, and epithelial). The presence of the bacteria in the hemocoele indicates the occurrence of a bacteremia, with death possibly resulting from a septicemia.

Not all strains of *Bacillus thuringiensis* tested were pathogenic for the rice weevil.

Table 2.—Results of infectivity tests in the rice weevil, *Sitophilus oryza* (Linn.), using various microorganisms.

Microorganism			Results with Test Insects						Results with Control Insects	
Name	Strain Number	Form of Microbial Preparation	Number Insects Tested	Total Number (and %) Dead	Number (and %) of Dead Not Infected	Per Cent of Total Dead Not Infected	Number (and %) of Dead Infected	Per Cent of Total Dead and Infected	Number Insects Tested	Number (and %) Dead (Not Infected)
Bacillus										
thuringiensis Berliner	0-3-30	suspension	20	9 (45)	0 (0)	0	9 (100)	45	20	4 (20)
thuringiensis Berliner	0-3-33	suspension	20	7 (35)	6 (86)	30	1 (14)	5	20	4 (20)
thuringiensis Berliner	57-1-1	suspension	20	1 (5)	1 (100)	5	0 (0)	0	10	4 (40)
thuringiensis Berliner	58-1-1	suspension	20	4 (20)	4 (100)	20	0 (0)	0	10	4 (40)
thuringiensis Berliner	B-14	dust	30	27 (90)	0 (0)	0	27 (100)	90	10	4 (40)
alvei C. & C.	0-3-1	suspension	10	5 (50)	3 (60)	30	2 (40)	20†	10	4 (40)
laterosporus Laubach	0-3-6	suspension	10	4 (40)	4 (100)	40	0 (0)	0	10	4 (40)
subtilis Cohn emend. Prazmowski	0-3-18	suspension	10	4 (40)	4 (100)	40	0 (0)	0	10	4 (40)
cereus F. & F.	0-3-23	suspension	20	9 (45)	2 (23)	10	7 (77)	35	10	4 (40)
megaterium De Bary	0-3-31	suspension	10	4 (40)	4 (100)	40	0 (0)	0	10	4 (40)
cereus var. *mycoides* (Flügge)	0-3-34	suspension	10	4 (40)	4 (100)	40	0 (0)	0	10	4 (40)
pumilis Bottheil	0-3-37	suspension	10	2 (20)	2 (100)	20	0 (0)	0	10	4 (40)
popilliae Dutky		suspension	10	0 (0)	0 (0)	0	0 (0)	0	10	1 (10)
popilliae Dutky } *lentimorbus* Dutky }		"Japonex" dust	40	40 (100)	40* (100)	100	0 (0)	0	40	40* (100)
Serratia										
marcescens Bizio	0-11-3	suspension	5	1 (20)	0 (0)	0	1 (100)	20	5	0 (0)
marcescens Bizio	0-8-7	suspension	5	4 (80)	4 (100)	80	0 (0)	0	5	0 (0)
marcescens Bizio	0-8-13	suspension	5	1 (20)	0 (0)	0	1 (100)	20	5	0 (0)
Sarcina lutea Schroeter	0-5-1	suspension	10	0 (0)	0 (0)	0	0 (0)	0	10	0 (0)
Pseudomonas sp.	25-22-2	suspension	10	0 (0)	0 (0)	0	0 (0)	0	10	0 (0)
Beauveria bassiana (Bals.)		dust	10	10 (100)	8 (80)	80	2 (20)	20	10	2 (20)
globulifera (Speg.)		dust	10	10 (100)	10 (100)	100	0 (0)	0	10	1 (10)
Metarrhizium sp. [probably *M. anisopliae* (Metch.)]		dust	10	3 (30)	3 (100)	30	0 (0)	0	10	1 (10)
Metarrhizium sp.		dust	10	5 (50)	5 (100)	50	0 (0)	0	10	1 (10)
Nosema sp. } *Plistophora* sp. }		suspension	10	1 (10)	1 (100)	10	0 (10)	0	10	2 (20)
Perezia pyraustae Paillot		suspension	10	0 (0)	0 (0)	0	0 (0)	0	10	2 (20)

* Deaths presumably caused by the talc used as a carrier in the spore powder "Japonex." Talc without spores was used in the controls.

† Although bacteria similar in morphology to *B. alvei* were seen in these dead insects, they were not identified and these deaths are of questionable etiology.

The greatest mortality (90 per cent) was obtained with strain B-14 used as a dust. Strains 0-3-30 and 0-3-33 killed 45 and 5 per cent respectively of the test weevils. No evidence of infection was obtained when strains 57-1-1 and 58-1-1 were used. (See table 1 for the original source of these strains.)

Since the tests just referred to were run with few weevils in a few grams of grain placed in petri dishes, it was considered advisable to perform similar tests using a greater number of insects in a greater quantity of grain. Accordingly, 250 rice weevils were placed in gallon jars containing 1200 grams of grain into which had been incorporated 5 grams of *Bacillus thuringiensis* spores. One such jar contained one-week-old spores, another two-year-old spores, and a third, the control, contained no spores. The jars were held at room temperature (about 25° C). After a period of 90 days (three months), and again after 150 days (five months), the dead and living weevils in each jar were counted and comparisons made. The results are presented in table 5 ("First Expt."). By the time the 90-day counts were made the population in the jar containing two-year-old spores, as well as that in the control jar, had increased from 250 to 682 insects and from 250 to 336 insects respectively. The probable reduction in numbers of living insects caused by the two-year-old spores apparently took place early and was missed by delaying the count for 90 days. A reduction (from 250 to 136 living weevils) was still evident in the case of the jar containing week-old spores, although the total population (living plus dead) was 379 insects.

After 150 days the numerical population increase was from 250 to 10,925 weevils (4351 per cent) in the jar containing grain treated with week-old spores, from 250 to 5658 (1890 per cent) in the jar containing grain treated with 2-year-

Table 3.—Results of infectivity tests in the granary weevil, *Sitophilus granarius* (Linn.), using various microorganisms.

Microorganism			Results with Test Insects						Results with Control Insects	
Name	Strain Number	Form of Microbial Preparation	Number Insects Tested	Total Number (and %) Dead	Number (and %) of Dead Not Infected	Per Cent of Total Dead Not Infected	Number (and %) of Dead Infected	Per Cent of Total Dead and Infected	Number Insects Tested	Number (and %) Dead (Not Infected)
Bacillus										
thuringiensis Berliner	0-3-30	Grain soaked in culture	20	9 (45)	2 (22)	10	7 (78)	35	20	5 (25)
thuringiensis Berliner	0-3-33	Grain soaked in culture	20	10 (50)	3 (30)	15	7 (70)	35	20	5 (25)
thuringiensis Berliner	57-1-1	Grain soaked in culture	20	5 (25)	4 (80)	20	1 (20)	5	10	5 (50)
thuringiensis Berliner	58-1-1	Grain soaked in culture	20	5 (25)	4 (80)	20	1 (20)	5	10	5 (50)
thuringiensis Berliner	B-14	Spore dust	30	10 (33.3)	0 (0)	0	10 (100)	33.3	10	2 (20)
alvei C.& C.	0-3-1	Grain soaked in culture	10	3 (30)	2 (67)	20	1† (33)	10	10	5 (50)
laterosporus Laubach	0-3-6	Grain soaked in culture	10	4 (40)	4 (100)	40	0 (0)	0	10	5 (50)
subtilis Cohn emend. Prazmowski	0-3-18	Grain soaked in culture	10	5 (50)	5 (100)	50	0 (0)	0	10	5 (50)
cereus F. & F.	0-3-23	Grain soaked in culture	20	3 (15)	2 (67)	10	1 (33)	5	10	5 (50)
megaterium De Bary	0-3-31	Grain soaked in culture	10	2 (20)	2 (100)	20	0 (0)	0	10	5 (50)
cereus F. & F. (var. *mycoides* Flügge)	0-3-34	Grain soaked in culture	10	5 (50)	5 (100)	50	0 (0)	0	10	5 (50)
pumilis Bottheil	0-3-37	Grain soaked in culture	10	4 (40)	4 (100)	40	0 (0)		10	5 (50)
popilliae Dutky	—	Grain soaked in culture	10	4 (40)	4 (100)	40	0 (0)	0	10	6 (60)
popilliae Dutky *lentimorbus* Dutky		"Japonex" dust	40	31 (77.5)	31* (100)	77	0 (0)	0	40	35* (87.5)
Serratia										
marcescens Bizio	0-11-3	Grain soaked in culture	5	0 (0)	0 (0)	0	0 (0)	0	5	0 (0)
marcescens Bizio	0-8-7	Grain soaked in culture	5	3 (60)	3 (100)	60	1 (100)	20	5	0 (0)
marcescens Bizio	0-8-13	Grain soaked in culture	5	1 (20)	0 (0)	0	0 (0)	0	5	0 (0)
Sarcina lutea Schroeter	0-5-1	Grain soaked in culture	10	0 (0)	0 (0)	0			10	0 (0)
Pseudomonas sp.	25-22-2	Grain soaked in culture	10	3 (30)	1 (33)	10	2 (67)	20	10	0 (0)
Beauveria										
bassiana (Bals.)	—	Spore dust	10	9 (90)	6 (67)	60	3 (33)	30	10	1 (10)
globulifera (Speg.)	—	Spore dust	10	10 (100)	10 (100)	100	0 (0)	0	10	6 (60)
Metarrhizium sp. (prob. *M. anisopliae*)	—	Spore dust	10	6 (60)	6 (100)	60	0 (0)	0	10	6 (60)
Metarrhizium sp.	—	Spore dust	10	5 (50)	5 (100)	50	0 (0)	0	10	6 (60)
Nosema sp. *Plistophora* sp.	—	Grain soaked in culture	10	4 (40)	4 (100)	40	0 (0)	0	10	1 (10)
Perezia pyraustae Paillot	—	Grain soaked in culture	10	1 (10)	1 (100)	10	0 (0)	0	10	1 (10)

* Deaths presumably caused by the talc used as a carrier in the spore powder "Japonex." Talc without spores was used in the controls.

† Although bacteria similar in morphology to *B. alvei* were seen in this dead insect they were not identified and this death is of questionable etiology.

old spores, and from 250 to 2617 (800 per cent) in the untreated control. During this time a total of 364 weevils had died in the first jar (of which 46.0 per cent of the dead at 90 days were infected and 83.4 per cent of the dead at 150 days, were infected with *Bacillus thuringiensis*), a total of 341 had died in the second jar (95.0 and 93.4 per cent of the dead were infected with *B. thuringiensis* at 90 and 150 days respectively), and a total of 283 died in the control jar none of these showing infection. In other words, starting with a given number of rice weevils in a jar with 1200 grams of grain, the population increase appeared to be significantly greater when *B. thuringiensis* was present than in controls in which this bacillus was not present. There also appeared to be a difference in population increase depending upon the age of the spores (a greater increase occurring when fresh spores were used).

The experiment just discussed was repeated (Table 5, "Second Expt.") using 100 weevils in 200 grams of wheat. In this instance, by the end of 30 days there had been a reduction in the number of living

Table 4.—Results of infectivity tests in the confused flour beetle, *Tribolium confusum* Duv., using various microorganisms.

Microorganism			Results with Test Insects						Results with Control Insects	
Name	Strain Number	Form of Microbial Preparation	Number Insects Tested	Total Number (and %) Dead	Number (and %) of Dead Not Infected	Per Cent of Total Dead Not Infected	Number (and %) Dead Infected	Per Cent of Total Dead Infected	Number Insects Tested	Number (and %) Dead (Not Infected)
Bacillus thuringiensis Berliner	0-3-30	Grain soaked in culture	20	1 (5)	0 (0)	0	1 (100)	5	20	0 (0)
thuringiensis Berliner	0-3-33	Grain soaked in culture	20	0 (0)	0 (0)	0	0 (0)	0	20	0 (0)
thuringiensis Berliner	57-1-1	Grain soaked in culture	20	4 (20)	3 (75)	15	1 (25)	5	10	1 (10)
thuringiensis Berliner	58-1-1	Grain soaked in culture	20	3 (15)	1 (33)	5	2 (67)	10	10	1 (10)
thuringiensis Berliner	B-14	Spore dust	30	2 (6.6)	0 (0)	0	2 (100)	6.7	10	0 (0)
alvei C. & C.	0-3-1	Grain soaked in culture	10	2 (20)	2 (100)	20	0 (0)	0	10	1 (10)
laterosporus Laubach	0-3-6	Grain soaked in culture	10	3 (30)	3 (100)	30	0 (0)	0	10	1 (10)
subtilis Cohn emend. Prazmowski	0-3-18	Grain soaked in culture	10	2 (20)	2 (100)	20	0 (0)	0	10	1 (10)
cereus F. & F.	0-3-23	Grain soaked in culture	20	2 (10)	0 (0)	0	2 (100)	10	10	1 (10)
megaterium De Bary	0-3-31	Grain soaked in culture	10	0 (0)	0 (0)	0	0 (0)	0	10	1 (10)
cereus F. & F. (var. *mycoides* Flügge)	0-3-34	Grain soaked in culture	10	3 (30)	3 (100)	30	0 (0)	0	10	1 (10)
pumilis Bottheil	0-3-37	Grain soaked in culture	10	2 (20)	2 (100)	20	0 (0)	0	10	1 (10)
popilliae Dutky	—	Grain soaked in culture	10	0 (0)	0 (0)	0	0 (0)	0	10	1 (10)
popilliae Dutky + *lentimorbus* Dutky		"Japonex" dust	40	14 (35)	14* (0)	35	0 (0)	0	40	31* (77.5)
Serratia marcescens Bizio	0-11-3	Grain soaked in culture	5	2 (40)	0 (0)	0	2 (100)	40	5	0 (0)
marcescens Bizio	0-8-7	Grain soaked in culture	5	0 (0)	0 (0)	0	0 (0)	0	5	0 (0)
marcescens Bizio	0-8-13	Grain soaked in culture	5	0 (0)	0 (0)	0	0 (0)	0	5	0 (0)
Sarcina lutea Schroeter	0-5-1	Grain soaked in culture	10	0 (0)	0 (0)	0	0 (0)	0	10	0 (0)
Pseudomonas sp.	25-22-2	Grain soaked in culture	10	0 (0)	0 (0)	0	0 (0)	0	10	0 (0)
Beauveria bassiana (Bals.)	—	Spore dust	10	5 (50)	2 (40)	20	3 (60)	30	10	2 (20)
globulifera (Speg.)	—	Spore dust	10	0 (0)	0 (0)	0	0 (0)	0	10	1 (10)
Metarrhizium sp. (prob. *M. anisopliae*)	—	Spore dust	10	2 (20)	2 (100)	20	0 (0)	0	10	1 (10)
Metarrhizium sp.	—	Spore dust	10	3 (30)	3 (100)	30	0 (0)	0	10	1 (10)
Nosema sp. + *Plistophora* sp.	—	Grain soaked in culture	10	2 (20)	2 (100)	20	0 (0)	0	10	2 (20)
Perezia pyrausta Paillot	—	Grain soaked in culture	10	2 (20)	1 (50)	10	1 (50)	10	10	2 (20)

* Deaths presumably caused by the talc used as a carrier in the spore powder "Japonex." Talc without spores was used in the controls.

insects in each of the three jars, the reduction in the jars containing spores of *Bacillus thuringiensis* being greater than that in the spore-free control jar. By the end of 60 days the number of living insects in each jar had increased to between 200 and 300 per cent. By the end of 150 days the total per cent increase ranged from 3981 in the control jar to 5484 per cent in the culture originally inoculated with week-old bacillus spores. The pattern of deaths and increases in the three cultures is, therefore, in general, the same for both the first and second experiments of this series. The relatively high percentage of early deaths in the infected cultures, as compared with the controls, and a later disproportionately large increase which more than compensates for the earlier population decrease in these cultures, indicates that in the case of the rice weevil the presence of *B. thuringiensis* acts as a strong selective agent. This results in the death of the weaker or less prolific insects or both, and the rapid evolution of a population which is not only resistant to the effects of *B. thuringiensis*, but has an unusually marked increase in reproductive capacity.

An experiment similar to that just de-

Table 5.—Counts made of rice weevil and granary weevil populations in wheat to which spores of *Bacillus thuringiensis* were added.

Insect Concerned	Time Counts Made	Grain Treated with *B. thuringiensis*								Control (*B. thuringiensis* not present)			
		One-Week Old Spores				Two-Year Old Spores							
		No. of Weevils		Per Cent of Dead Infected	Per Cent Total Increase	No. of Weevils		Per Cent Dead Infected	Per Cent Total Increase	Number of Weevils		Per Cent of Dead Infected	Per Cent Total Increase
		Living	Dead			Living	Dead			Living	Dead		
Rice Weevil (First Expt.) (1200 grams of wheat)	Start	250	0	—	—	250	0	—	—	250	0	—	—
	90 days	136	243	46	52	682	194	95	254.0	336	199	0	130
	150 days	10,561	121	83	4351	5317	147	93	1890.0	2334	84	0	800
Rice Weevil (Second Expt.) (200 grams of wheat)	Start	100	0	—	—	100	0	—	—	100	0	—	—
	30 days	66	33	82	0	79	21	76	0	89	11	0	0
	60 days	283	23	100	239	362	16	94	299	310	28	25	249
	90 days	1251	20	100	1227	1284	20	100	1241	1009	36	20 *B. thur.**	984
	150 days	4576	932	46	5484	3897	728	43	4582	3150	856	0 *B. thur.**	3981
Granary Weevil (200 grams of wheat)	Start	100	0	—	—	100	0	—	—	100	0	—	—
	30 days	50	4	100	0	95	5	80	0	99	1	0	0
	60 days	651	11	100	562	968	8	100	881	1079	3	0	983
	90 days	2625	15	100	2555	3436	24	100	3373	3748	48	0	3700
	120 days	4527	912	12	5369	6376	535	24	6848	8040	452	0	8444

Infections in weevils determined by stained smears.

* The contamination of the control at this point of the experiment may well account for the relatively greater percentage increase in this control as compared with the control of the first experiment.

scribed was performed with the granary weevil as the test insect. In this case the results are just the opposite from those experiments involving the rice weevil. From table 5 it may be seen that the presence of week-old *Bacillus thuringiensis* spores in the culture of granary weevils reduced the percentage of total increase (at the end of a 60-day period) to 566 per cent as compared with a total increase in the control culture of 983 per cent at this stage of the experiment. This significantly greater percentage of increase was maintained by the control culture, and at the final (120-day) check of this experiment the living population of the control was almost twice that of the living population of the infected culture. It might also be pointed out that despite the larger population the number of dead in the control culture was slightly less than half the number of dead in the smaller culture containing fresh *B. thuringiensis* spores. As in the previous experiments with rice weevils the two-year-old spores seemed to have lost some of their infective power and the results of this culture again appear as intermediate between the control culture and the fresh (one week old) spore culture.

The consistent and relatively rapid drop in the percentage of dead weevils with *Bacillus thuringiensis* after 90 days in the last two experiments shown in table 5, does not necessarily indicate increased resistance to the bacillus on the part of the insects (see 150 day check, Expt. 1, table 5). This reduction in infectivity might possibly be due to some factor in the smaller cultures which in time inhibits the bacillus or reduces its infectivity. After 90 days there was evidence of an intercurrent infection (micrococcus) in the second and third experiments which may also account for a lower rate of *B. thuringiensis* infection.

Sitophilus granarius.—The granary weevil showed varying degrees of apparent susceptibility to five species of microorganisms tested: *Bacillus thuringiensis* (five strains), *Bacillus cereus*, *Serratia marcescens*, an unidentified species of *Pseudomonas*, and *Beauveria bassiana*. As in the case of the experiments using the rice weevil as the test insect, only *B. thuringiensis* exhibited a convincing degree of pathogenicity for the granary weevils tested. The fungus *B. bassiana* appeared to be present in the dead bodies of three out of 10 weevils tested, but whether or not this represented a primary infection is difficult to decide since six of the remaining weevils in the same lot of 10 also died, apparently from amicrobic causes.

Deaths apparently caused by infection

with *Bacillus thuringiensis* occurred over approximately the same period of time as was the case with the rice weevil—from 3 to 24 days after exposure. When aqueous suspensions of spores were used to treat the grain, most of the granary weevils died between the 8th and 14th days. When spore dust was used most of the deaths took place between the 14th and 21st days.

Symptomatology and the histopathology picture in the granary weevils infected with *Bacillus thuringiensis* were essentially the same as those already described as found in the rice weevil.

All five strains of *Bacillus thuringiensis* used in the tests showed at least some infectivity for the granary weevil. However, two of the strains (57-1-1 and 58-1-1) infected only one out of the 20 insects used in each test. These were the same two strains that showed no infectivity for the rice weevil.

The remaining three strains (0-3-30, 0-3-33, and B-14) showed an almost equal per cent mortality apparently caused by the bacillus (*i.e.*, about 35 per cent).

Tribolium confusum.—The confused flour beetle showed very little definite susceptibility to any of the test microorganisms. A slight degree of infectivity was exhibited by *Bacillus thuringiensis* and *B. cereus*, while a moderate degree of infectivity appeared to be associated with one strain of *Serratia marcescens* and with *Beauveria bassiana*. Of the five strains of *B. thuringiensis* used, two strains each infected one out of 20 test insects, one infected 2 out of 30, and one infected 20 out of 20, and one strain infected none out of 20 test insects. *B. cereus* infected 2 out of 20, one strain of *S. marcescens* infected two out of five, and *B. bassiana* infected three out of 10 test insects. In no instance can the number or percentage of insects becoming infected be considered impressive.

OTHER STORED-GRAIN INSECTS.—Although most of the experimentation in this study was confined to the rice weevil, the granary weevil, and the confused flour beetle, some tests were run using the lesser grain borer, *Rhizopertha dominica* (Fabr.), and the angoumois grain moth, *Sitotroga cerealella* (Oliv.).

The lesser grain borer, in lots of 10 insects each, was found to be insusceptible to all organisms tested. These included *Bacillus thuringiensis, B. popilliae, Beauveria bassiana, B. globulifera, Metarrhizium* spp., and *Perezia pyraustae*. As in the previous tests, however, the fungi were used under conditions of prevailing atmospheric humidity (relative humidity in the neighborhood of 70 per cent). Unless the spores of the fungi were ingested, there would probably be little opportunity for their germination and subsequent penetration of the insect by means of infection hyphae.

The angoumois grain moth was resistant to infection by the three strains of *Serratia marcescens* tested but did show some susceptibility to *Bacillus thuringiensis*. One strain (0-3-30) of this bacillus infected four out of the five insects used in this particular test. Another strain (0-3 33) showed no pathogenicity for the moth in a similar test.

TESTS OF THE TOXIC EFFECT OF *Beauveria bassiana*.—In 1950, Dresner reported that the germinating spores of *Beauveria bassiana* (Balsamo) produce a toxin that acts as a contact poison, and that may paralyze an insect even in advance of the invasion of the insect body by hyphae of the fungus. The insects used in his studies were adults of the house fly, *Musca domestica* Linn.; adults of the green dock beetle, *Gastroidea cyanea* Melsh.; and larvae of the potato tuberworm, *Gnorimoschema operculella* (Zeller). All three of these insects appeared to become paralyzed on exposure to the germinating *Beauveria* spores in much less time (less than 2 hours in many experiments) than that required for actual infection to take place. The principal strain of *B. bassiana* used was one obtained from the American Type Culture Collection.

In the hope that the toxic principle described by Dresner could be used against stored grain insects, an attempt was made to repeat his experiments and to test the possible susceptibility of the grain insects to it.

Two strains of *Beauveria bassiana* were used in our experiments. One (our strain No. F25-2-4) had originally been isolated from diseased larvae of the European corn borer, *Pyrausta nubilalis* (Hbn.); the other, presumably the strain used by Dresner, was obtained from the American Type Culture Collection (No. 9835). The techniques used in making the tests were

essentially the same as those described by Dresner (1950).

In our hands, there appeared to be only a slight and inconsistent toxic reaction when the house fly was used as the test insect. This was true both when the fungus spores (fresh as well as several months old) were applied directly and after they had been permitted to germinate in such media as milk and glucose broth which was made available to the flies as food. No clear toxic effect was observed in larvae of the potato tuberworm exposed to the fungus spores.

In spite of these negative or inconclusive results, the possible toxic effect of *Beauveria* spores to certain of the stored-grain insects was tested. The insects used were adults of the granary weevil, the rice weevil, the confused flour beetle, and the angoumois grain moth. None of these insects showed any significant toxic reaction to contact with the fungus spores. Accordingly, this approach to finding a means of controlling stored-grain insects was abandoned.

DISCUSSION OF INFECTIVITY TESTS.—The results of the infectivity tests conducted in the present investigation indicate that of the 27 different strains of microorganisms used, only those of *Bacillus thuringiensis* showed any consistent and significant pathogenicity for the test insects. Although strains of certain other species showed some powers of infectivity they were either not as consistent in this regard or as promising from the standpoint of their possible use as control agents. More extensive and detailed study, however, may require a revision of this appraisal.

Bacillus thuringiensis is a gram-positive sporeforming bacterium originally isolated in 1911 by Berliner from diseased larvae of the Mediterranean flour moth, *Ephestia kühniella* Zeller. It has since been found to be pathogenic for such insects as the cosmopolitan bran beetle, *Echocerus cornutus* (Fabr.); the European corn borer, *Pyrausta nubilalis* (Hbn.), the alfalfa caterpillar, *Colias philodice eurytheme* Boisduval, the imported cabbageworm, *Pieris rapae* (Linn.), the fawn-colored lawn moth, *Crambus bonifatellus* (Hulst), and certain other Lepidoptera.

Taxonomically, *Bacillus thuringiensis* is either a variety of, or closely related to, *Bacillus cereus* Frankland & Frankland. It differs from the latter organism primarily in its pronounced pathogenicity for insects, and in the fact that in nearly all strains of *B. thuringiensis* so far studied, the spore lies obliquely within the sporangium. *B. cereus* itself has been reported as causing disease in insects, and it was one of the bacteria apparently capable of infecting the stored-grain insects used in the present investigation. However, most of the typical strains of *B. cereus*, such as those isolated from the soil, do not have a pronounced capacity to infect many insects (especially certain Lepidoptera) as does *B. thuringiensis*. Further information concerning the relation between *B. thuringiensis* and *B. cereus* is included in an earlier publication (Steinhaus 1951).

Five different strains of *Bacillus thuringiensis* were used in the work here being reported (see table 1). In general, the strains (0-3-30 and 0-3-33) originally isolated from *Ephestia kühniella* Zeller (by Mattes in 1927), and the strain (B-14) isolated from an unidentified *Peridroma* larva appeared to have greater pathogenicity for the granary and rice weevils than did those (57-1-1 and 58-1-1) from *Plodia interpunctella* (Hbn.) and *Aphomia gularis* (Zeller). Whether or not this apparent strain difference is significant is difficult to say without further testing. At any rate, strains 0-3-30 (suspension) and B-14 (dust) appeared to be the strains of choice from the standpoint of infectivity for the granary and rice weevil.

Large-scale experiments designed to test the efficiency of *Bacillus thuringiensis* as a practical control agency in storage bins and elevators have not been run. However, the experiments performed in which the effect of the bacillus on 250 weevils in 1200 grams of grain and on 100 weevils in 200 grams of grain tested may give some indication as to what could happen in regular storage bins. In any case, methods by which spores of the bacillus can be produced in relatively large quantities have been devised and perfected on a "pilot-plant" basis. Most of these production techniques have been worked out in this laboratory in connection with other projects, but the knowledge so gained has been used in the present investigation.

The spore dust used in our experiments was prepared in a manner similar to that described by Steinhaus (1951) and by Hall (1952).

In considering the possible application of *Bacillus thuringiensis* in the control of stored-grain pests, it is necessary to realize that even though the bacillus has shown a moderate degree of pathogenicity for the insects concerned, it has by no means demonstrated a uniformly marked degree of virulence for all of the individuals making up a test lot of insects. In no case were more than 90 per cent of the beetles in any one lot infected with the bacillus, and usually the per cent infected was much smaller (*e.g.*, 5, 35, and 45 per cent). Furthermore, there was at least some indication that after an initial reduction in the size of the population, during which time infected insects may be found, the number tends to increase rapidly again even surpassing that in untreated grain. Thus, although the possibility of the practical control of stored-grain pests by means of *B. thuringiensis* cannot be ruled out, it is indicated that rapid control on a basis equal to that of the best type of chemical control does not appear to be very promising. It is to be remembered, however, that since the weevils, under certain conditions at least, are susceptible to infection by the bacillus, the reason there is not a more uniform kill may be related to the manner and frequency with which the spores come in contact with the insect. Further investigation of these factors may yield information that would enhance the possible use of the bacillus in controlling the insects concerned.

It might be pointed out that on the basis of the work of other investigators, it does appear that *Bacillus thuringiensis* may offer some promise against such insects as the Mediterannean flour moth, *Ephestia kühniella* Zeller, found in meal and flour. In 1927, Berliner suggested that the spores of the bacillus be incorporated with the grain prior to the milling process and that such application would be sufficient to suppress the flour-moth likely to occur in untreated flour. Mattes (1927), without actually testing it, was not convinced as to the economic practicability of Berliner's suggestion, but he did confirm the high degree of susceptibility shown by the flour-moth larvae to *B. thuringiensis*. However, Mattes found that his own method of applying spore powder directly to the flour and milling equipment was not uniformly successful in controlling the pest because the webs of the insect protected it from contact with the infectious spores. Since there was no practical way of penetrating the webs with the spore material, the larvae inside the webs did not have an opportunity to feed on spore-laden flour.

More recently, Jacobs (1950) reported on the bacteriological control of the Mediterranean flour moth using a French product having the trade name "Sporeine." We have been unable to learn the exact nature of the bacterial spores making up this product but it would appear to be of the *Bacillus thuringiensis* type. The product was described as containing 10 per cent by weight of spores of bacteria pathogenic for insects, in bentonite. According to Jacobs, in whole-meal flour between 0.1 and 0.3 per cent by weight of this spore powder completely prevented the development of infestation by newly-hatched larvae. "Infestations of whole meal flour in sheds were checked considerably by the application of surface deposits of the spores, established by dusting the dry powder or spraying a suspension in water."

In our own laboratory we have confirmed the marked susceptibility of the Mediterranean flour moth to *Bacillus thuringiensis*, but have made no tests as to its applicability in mills. From all the evidence at hand, however, it would appear that more comprehensive work should be done on the possibilities of using this bacillus in controlling the flour moth. Indications are that its incorporation into the flour or mill products would be entirely harmless both to the products concerned and to the consumers. It could be readily and inexpensively applied and its effectiveness would probably be great enough to make it entirely worth while.

Results obtained in the present investigation indicate some degree of pathogenicity for the test insects on the part of *Serratia marcescens* Bizio. From a practical standpoint, however, this red-pigmented bacterium would have at least two drawbacks as far as its use in control is concerned. In the first place, unless white variants were used, the red-pig-

DIGITIZED BY MICHIGAN LIBRARIES

mentation of the organism would be likely to color the product. In the second place the bacterium is not a sporeformer and hence, although it is a fairly long-lived nonsporeformer (Steinhaus 1939), it would not have the durability of a sporeformer such as *Bacillus thuringiensis*.

The fact that the fungus *Beauveria bassiana* (Bals.) caused from 20 to 30 per cent infection in three of the test insects is interesting in light of the adverse humidity conditions provided the microorganism. It is generally accepted that fungi of the *Beauveria* type require a relative humidity of 90 per cent or more for germination of the conidia. In this investigation the tests were run at humidities in the neighborhood of only 70 per cent. Higher humidities were not used because it has been shown that a high relative humidity is damaging to the grain through microbial action. Fungi were, however, used in our infectivity tests on the assumption that some of the conidia might be ingested by the insects and that the moisture content of their alimentary tracts would be sufficient to germinate the conidia. Although the usual route of infection by fungi attacking insects is through the integument directly into the body cavity, there is evidence that infection by way of the digestive tract occurs not infrequently with certain entomogenous fungi. Perhaps the instances of infection by *B. bassiana* obtained in our experiments can be explained on such a basis. In any case, infection of the test insects with *B. bassiana* under the conditions of our experiments, although interesting and somewhat unexpected, was not significant enough to suggest the use of this fungus in the practical control of the insects. If the grain could be held in the presence of more moisture, it would appear that *B. bassiana* might be an effective pathogen for the insects concerned.

Although the three species of protozoa used in our experiments were all responsible for infections in other insects, none of them showed a significant degree of pathogenicity for the test insects. This was not unexpected since insects of the type found in stored whole-grain are not known to be as ready natural hosts for protozoa as are many other groups of insects. Indeed, microbiological examinations of normal granary and rice weevils did not reveal the presence of any significant microbiota when examined during the present investigation. In fact, most specimens appeared essentially to be microbiologically sterile as far as the presence of extracellular microorganisms in their internal anatomy was concerned.

EFFECT OF ANTIBIOTICS ON CERTAIN STORED-GRAIN INSECTS.—Inasmuch as the experiments performed to test the susceptibility of stored-grain insects to certain bacteria, fungi, and protozoa did not produce very promising results, at least from the standpoint of their possible use in controlling the insects, we turned our attention to another aspect of insect microbiology. That many of the insects found in stored-grain harbor living microorganisms within certain tissue cells has been known for some time. The role of these intracellular symbiotes, as they are called, is known in a few species of insects. In some insects, such as the drug-store beetle and cockroaches, it appears that the symbiotes produce essential vitamins and possibly hormone substances. In aphids it has been claimed that the symbiotes fix atmospheric nitrogen. In the case of the stored-grain insects, the physiological relationship between the symbiotes and the insects has not been determined. However, since the symbiotes in these insects appear to be in as intimate a relationship as in most other symbiote-bearing insects, there is reason to believe they may provide their hosts with metabolic essentials of one sort or another. On the basis of such an assumption it was decided to investigate the possibility of killing or preventing the reproduction of stored-grain insects by depriving them of their symbiotes through the use of antibiotics.

That at least some insects can be freed of their symbiotes by means of antibiotics is indicated by the experiments of Brues & Dunn (1945) and by Glaser (1946) on cockroaches. These workers found that the administration of sub-toxic doses of penicillin greatly reduce the number of intracellular symbiotes in the bacteriocytes of the roach, and that this decrease in numbers is accompanied by a deficiency of certain unidentified constituents essential to the health of the insect. More recently, Musgrave & Miller (1951) reported that when the granary weevil and

the rice weevil were fed terramycin-treated grain both species showed some degree of mortality over that in untreated controls, but that the rice weevil fed terramycin "is disturbed metabolically to a markedly greater extent" than the granary weevil similarly treated. They suggested that "this difference may be due to the inhibition of vitally important symbionts" in the rice weevil. At the time Musgrave & Miller wrote their paper they assumed, on the basis of Mansour's (1934) observations, that whereas the rice weevil harbored symbiotes, the granary weevil did not. Further observations have shown that both weevils do harbor symbiotes as had been shown earlier by Buchner (1930).

Unfortunately, the investigation here being reported had to be suspended before the effect of antibiotics on the symbiotes could be ascertained, but the general effect of relatively large doses of the drugs on the insect as such was noted and these observations are being presented as a preliminary report.

MATERIALS AND METHODS.—In the experiments to be described the following antibiotics were used: aureomycin (Lederle), bacitracin (Commercial Solvents), chloromycetin (Parke, Davis) penicillin G (Parke, Davis), polymixin B (Commercial Solvents), streptomycin (Merck), and terramycin (Pfizer). The insects used in these experiments were the granary weevil, the rice weevil, the lesser grain borer, and the confused flour beetle. The manner in which these insects were maintained was identical to that described in the first section of this paper.

Most of the experiments were set up in dual fashion (plus controls): in one instance the antibiotic was added to the grain in a powdered form; in the other set-up the antibiotic was placed in solution and the grain was allowed to become coated with it. Each lot of grain and test insects were held in large (1 by 4 inch) vials the mouths of which were covered with gauze. At regular intervals each vial was examined to determine the number of dead and living insects it contained, and the freshly dead weevils were examined for the presence of intracellular symbiotes.

The dosage of antibiotic used varied from as high as 0.5 gram per 14 grams of wheat to as low as 0.01 gram of antibiotic per 14 grams of wheat.

RESULTS OF ANTIBIOTIC TESTS.—In some respects the results obtained in the experiments designed to study the effect of antibiotics on stored-grain insects and their intracellular symbiotes proved to be indefinite and inconclusive. On the other hand, some interesting and pertinent observations were made during the course of these studies, and these appear to deserve recording. Unfortunately, circumstances have prevented the continuation of the project at this time, so that the results obtained are being reported here as of preliminary significance only.

As can be seen from the data presented in table 6, all seven of the antibiotics used in these experiments brought about the death of 100 per cent, or nearly 100 per cent, of the adults of the granary and rice weevils and *Tribolium* within a 30 to 60 day period. In the case of the lesser grain borer (*Rhizopertha*), however, one of the antibiotics (terramycin) was more or less neutral in its action, and only one (streptomycin) gave a significant kill. The remaining five, especially chloromycetin, appeared to be somewhat stimulatory in action. Inasmuch as the other powdered antibiotics did not kill *Rhizopertha*, it does not appear likely that the kill in the case of streptomycin powder was caused by its physical form.

In order to verify the apparent stimulatory effect of chloromycetin on *Rhizopertha*, another experiment was set up in which the drug was added to lots of grain containing 50 insects each and counts of the number of insects present after 30 and 60 days were made. In one instance, *Rhizopertha* that had been exposed to chloromycetin in the preceding experiment were subjected to 0.5 gram of chloromycetin (in 14 grams of grain). The control also consisted of insects that had been previously exposed to the drug. After a period of 60 days the number of insects in the chloromycetin-treated group had increased from 50 to 467 with 20 insects found dead, while the control increased from 50 to 436 borers with 30 found dead. The insects that had been twice exposed to chloromycetin (presumably during two generations) produced a population approximately 20 per cent larger (90 more individuals) than did the

Table 6.—The number of dead and living stored-grain insects in lots treated with various antibiotics in both powder and solution form, and after periods of 30 and 60 days.

Antibiotic	Dosage Grams[1]	Powder						Solution					
		After 30 Days			After 60 Days			After 30 Days			After 60 Days		
		Living	Dead	%D	L	D	%D	L	D	%D	L	D	%D
Granary weevil, *Sitophilus granarius* (Linn.)													
Aureomycin	0.3	0	59	100	0	0	—	0	50	100	0	0	—
Bacitracin	0.5	10	42	81	0	11	100	27	23	46	4	21	84
Chloromycetin	0.5	25	29	53	0	24	100	36	11	24	4	31	89
Penicillin	0.5	31	22	42	0	33	100	27	23	46	0	26	100
Polymixin	0.5	30	21	42	0	1	100	0	57	100	0	0	—
Streptomycin	0.5	2	48	96	0	2	100	15	40	73	0	15	100
Terramycin	0.5	0	58	100	0	2	100	0	51	100	0	0	—
Control	0.0	40	14	26	19	21	53	—	—	—	—	—	—
Lesser grain borer, *Rhizopertha dominica* (Fabr.)													
Aureomycin	0.3	25	27	52	167	37	18	10	38	23	170	42	20
Bacitracin	0.3	27	27	50	358	19	5	35	14	28	411	4	1
Chloromycetin	0.5	22	29	57	402	11	3	34	8	26	389	13	3
Penicillin	0.5	34	41	58	296	8	4	42	12	22	319	15	4
Polymixin	0.5	26	24	48	310	14	4	14	37	73	202	5	2
Streptomycin	0.5	1	52	98	0	1	100	23	29	56	241	8	3
Terramycin	0.5	2	49	96	86	12	12	14	34	71	56	40	42
Control	0.0	20	41	67	201	1	1	—	—	—	—	—	—
Rice weevil, *Sitophilus oryza* (Linn.)													
Aureomycin	0.3	0	63	100	0	0	—	0	50	100	0	0	—
Bacitracin	0.3	5	48	90	0	5	100	7	45	86	2	5	71
Chloromycetin	0.5	11	0	0	0	23	100	8	44	85	1	7	88
Penicillin	0.5	20	35	64	0	22	100	18	35	66	0	19	100
Polymixin	0.5	42	4	9	0	37	100	50	6	11	0	46	100
Streptomycin	0.5	4	53	93	0	4	100	10	16	62	1	110	99
Terrmycin	0.5	0	21	100	0	0	—	0	48	100	0	0	—
Control	0.0	31	16	34	0	33	100	—	—	—	—	—	—
Confused flour beetle, *Tribolium confusum* Duv.													
Aureomycin	0.3	0	46	100	0	0	—						
Bacitracin	0.3	0	50	100	0	0	—						
Chloromycetin	0.3	2	45	96	1	1	50						
Penicillin	0.3	3	38	93	14	4	22						
Terramycin	0.3	0	51	100	0	0	—						
Control	0.0	11	38	78	6	6	50						

[1] Dosage in grams per 14 grams of grain.

control referred to in the next paragraph, that had never been exposed to the drug.

The experiment was then repeated using fresh insects, that is, insects not previously exposed to chloromycetin. In this instance, the number of borers increased from 50 to 417, with 17 dead, in 60 days when exposed to chloromycetin, while the control, containing none of the drug, increased from 50 to 377, with 19 found dead. In both experiments there was a slight drop in the number of insects to slightly below 50 at the end of 30 days. This was overcome during a period of from 30 to 60 days.

The manner of administering the antibiotics in all our experiments was such as to permit both ingestion of the antibiotic and external contact with the drug by the insect. An effort was made to obtain some indication as to whether or not the toxin effect of aureomycin, as an example, for the rice weevil was the result of contact between the drug and the insect's integument, rather than the result of ingestion. To accomplish this, three series of three vials each were set up: a control series with no antibiotics, a series in which all the insects were lightly dusted with aureomycin before being placed in the vials, and a series in which the internal surface of the vial was coated with aureomycin solution that was evaporated to leave a thin, even coating of the antibiotic on the glass. The three vials of each series offered different conditions to the insects. One vial in each series remained empty except for its insect population and (except for the control) the antibiotic that was either dusted on the insects or allowed to coat the vial's walls. A second vial of each series contained wood pellets, cut to

simulate grain but to offer no food to the insects. The third vial in each series contained 10 grams of untreated wheat.

Within a period of seven days all the weevils (100 in each vial) in both the "empty" (no pellets and no wheat) vials and the vials containing wood pellets in each series had died, with no deaths occurring during the first three days and most of them occurring on the fifth day. The pattern of deaths was the same for the control series as for the two series treated with antibiotic—the presence of the antibiotic externally having no visible effect on the death rate, even though the weevils became thoroughly covered with it. All deaths in these vials then were presumably due to starvation. In the vials containing wheat much of the antibiotic was transferred from the insects or the vial wall to the grain (except in the antibiotic free control series) and in such cases where the insects could chew on "treated" grain the pattern of deaths was similar to that in the majority of the other antibiotic experiments with the death periods more protracted, and presumably due to the effect of ingested antibiotic and not starvation.

In 1951, Musgrave & Miller presented data which they believed indicated that rice and granary weevils fed terramycin-treated grain, both show some mortality greater than occurs with untreated controls, and that the rice weevil is disturbed metabolically to a greater extent than is the granary weevil. Our experiments with terramycin, and which more or less paralleled those of Musgrave & Miller, indicated that both species are affected to about the same extent by this antibiotic. There were some differences in the details of the experimentation of the two groups of workers; (numbers of insects and period of observation) these are shown in table 7, along with a comparison between our data and those obtained by the Canadian workers.

Additional replicates and experiments along this line were run using terramycin powder (0.25 gram per 14 grams of grain), terramycin solution (0.25 gram in 10 ml. water per 14 grams of grain) and sterilized terramycin solution (of the same strength as above). The results of these experiments substantiated our results shown in table 7. At the end of 30 days the insects in the vials containing the grain treated with terramycin powder showed a mortality of 64 per cent in the case of the rice weevils and 90 per cent in the case of the granary weevils. After 60 days the remaining insect populations of these vials showed an additional 25 per cent mortality in the case of the rice weevils, but no further deaths occurred among the few granary weevils. The mortality among the insects in the cultures

Table 7.—A tabular comparison of the data from the present investigation and those (relating to the effect of terramycin on the rice and granary weevils) obtained by Musgrave & Miller (1951).

	Sitophilus oryza (LINN.)		*Sitophilus granarius* (LINN.)	
	Fed Water-Treated Grain	Fed Terramycin-Treated Grain	Fed Water-Treated Grain	Fed Terramycin-Treated Grain
Number at Start	50 (20)	50 (20)	50 (20)	50 (20)
Number after 30 Days Number after 72 Days	31 (79)	0 (24)	40 (57)	0 (41)
Population increase	0 (59)	0 (4)	0 (37)	0 (21)
Approx. % mortality	40 (11)	100 (84)	20 (11)	100 (32)
Condition of grain[1]	B (B)	C− (C)	A (A)	C− (B)

Dose: 0.036 gram terramycin per gram of grain.
The first row of figures running across the page represents data obtained in a single experimental set-up of the authors' experiments. The figures (in parentheses) from the paper by Musgrave and Miller are means of three replicates.
[1] *Condition of grain:* A = very well eaten (only husks and powder); B = well eaten; C = eaten slightly.

treated with sterilized terramycin solution was low (10 to 13 per cent) comparable with results in the controls.

Since the stored-grain insects used in our experiments showed a distinct, although variable, susceptibility to the action of the antibiotics used, it was decided to test the action of these drugs on a few other species of insects.

In general, it was found that house flies were readily killed by two per cent chloromycetin and one per cent bacitracin, penicillin, terramycin, and streptomycin. The insects succumbed in a manner suggesting a toxification of the nervous system. DDT-resistant flies did not show any significant degree of resistance to the antibiotics.

In light of the work by Brues & Dunn (1945) and by Glaser (1946) on the removal of intracellular symbiotes from cockroaches by the administration of subtoxic doses of penicillin, it was thought advisable to examine the insects with which we were working with regard to the status of their intracellular symbiotes. Musgrave & Miller (1951) suggested that the difference they observed in the susceptibility of the rice weevil and the granary weevil to the action of terramycin might be due to the "inhibition of vitally important symbionts" in the rice weevil.

Buchner (1930) has already demonstrated the presence of intracellular symbiotes in both the rice weevil and the granary weevil. We were able to confirm Buchner's observations, rodshaped symbiotes being present in the adult as well as the immature stages of both species of weevils. Sections of healthy weevils showed the presence of mycetome containing the symbiotes, in the manner described by Buchner. Sections of weevils killed by antibiotics were difficult to study because of the disintegration of tissues that had occurred in the particular specimens examined. It was at this point that our studies were suspended. The next step in the investigation would be comparative study of the symbiotes of normal and antibiotic-treated weevils.

DISCUSSION OF ANTIBIOTIC TESTS.—Our investigation of the effect of antibiotics upon stored-grain insects is admittedly far from complete. Whether or not it is possible to remove the insects' intracellular symbiotes by means of antibiotics cannot be ascertained from the data herein presented. Nor does the data give us any positive idea that the removal of the symbiotes by this means would harm or kill the insects. The doses of antibiotics used in our studies were sufficient to be toxic to most of the stored-grain insects tested. To study the effect of the removal of the symbiotes upon the health of the insects it would be necessary to use doses sufficient to destroy the symbiotic microorganisms but at the same time not be toxic to or kill the host insect. It is to be hoped that a continuation of an investigation along these lines will be possible.

Inasmuch as relatively large doses (0.3 to 0.5 gram per 14 grams of grain) were used, it is perhaps not surprising that a considerable degree of toxicity to the test insects were shown. Nevertheless, it may be significant that the lesser grain borer did not show the high susceptibility to most of the antibiotics that did the rice and granary weevils and the confused flour beetle. Also of significance may be the fact that the lesser grain borer showed considerable difference in its susceptibility to the seven antibiotics tested. Whereas streptomycin killed 100 per cent of the insects in 30 to 60 days, terramycin showed no particular effect, and the remaining five showed some indication of producing a stimulatory effect as far as the numerical increase of the insects is concerned. Chloromycetin was particularly indicative in this respect, although repeated experiments showed this effect not to be exceptionally strong.

The mode of action of the antibiotics used in these experiments was not investigated by us. On the basis of symptomatology in house flies exposed to the drugs, it is possible that at least some of them act as nerve poisons. The possibility of using antibiotics for their insecticidal value was not investigated, but it is likely that when compared with other available poisons their toxicity in high dilutions would be insufficient to make their use economical. Their use in this regard, however, should not be dismissed without further investigation particularly with respect to the principle of controlling insects through the destruction of their symbiotes by means of antibiotics and related compounds.

It is somewhat difficult to explain completely the discrepency between our re-

sults and those obtained by Musgrave & Miller (1951) concerning the effect of terramycin on the rice and granary weevils. Whereas they found the rice weevil to be more susceptible to the action of terramycin than the granary weevil, we found no such difference. Since both species harbor symbiotes it is not likely that their results can be explained on the erroneous supposition (Mansour 1934) that the mycetome of the granary weevil contains no symbiotes.

SUMMARY.—In general, coleopterous stored-grain insects (the granary weevil; *Sitophilus granarius* (Linn.), the rice weevil, *Sitophilus oryza* (Linn.); the lesser grain borer, *Rhizopertha dominica* (Fabr.); and the confused flour beetle *Tribolium confusum* (Duv.)) do not show a high degree of susceptibility to entomogenous microorganisms (bacteria, fungi and protozoa) under conditions optimum for the growth and development of the insects. Of the several species of microorganisms tested, only *Bacillus thuringiensis* Berliner, showed significant pathogenicity for the granary and rice weevils. Certain other microorganisms were occasionally capable of infecting the test insects, but in none of these instances could the infections be uniformly initiated, nor did there appear to be any real possibility of their practical use in the control of the insects.

Further tests on the possible application of *Bacillus thuringiensis* in the control of stored-grain pests (especially lepidopterous insects) would be worthwhile. With regard to the granary and rice weevils, *B. thuringiensis* did not infect more than 90 per cent of the insects, and there was some indication that a weevil population may overcome the infection and increase rapidly to a point surpassing that in untreated grain. Therefore, although the possibility of controlling stored-grain insects on a practical basis by means of *B. thuringiensis* cannot be ruled out, it would appear that rapid control with this bacterium on a basis equal to that of the best type of chemical control is not very promising.

In the course of making preliminary tests as to the feasibility of depriving stored-grain beetles of their intracellular bacterial symbiotes by means of antibiotics, it was found that these drugs are toxic to most of the insects tested. Relatively large doses (0.3 to 0.5 gram per 14 grams of grain) of aureomycin, bacitracin, chloromycetin, penicillin G, polymixin B, streptomycin, and terramycin killed 100 per cent of the granary and rice weevils tested within 30 to 60 days. Similar results were obtained in the case of *Tribolium*, but the lesser grain borer showed considerable variation in its reaction to the antibiotics. The latter insect was more or less neutral in its reaction to terramycin, it was killed by streptomcyin, and appeared to be slightly stimulated (from a reproductive standpoint) by chloromycetin.

In contrast with the results obtained by Musgrave & Miller, the data obtained in our experiments showed no significant difference in the reactions of the rice weevil and the granary weevil to terramycin.

A study of the direct effect of antibiotics on the intracellular symbiotes was not included as a part of this particular investigation.

LITERATURE CITED

Berliner, E. 1911. Über die Schlaffsucht der Mehlmottenraupe. Ztschr. f. das Gesam. Getreidewesen. **3**: 63–70.

Berliner, E. 1915. Über die Schlaffsucht der Mehlmottenraupe (*Ephestia kühniella*, Zell.) und ihren Erreger *Bacillus thuringiensis*, n. sp. Ztschr. f. Angew. Ent., **2**: 29–56.

Brues, C. T., and R. C. Dunn, 1945. The effect of penicillin and certain sulfa drugs on the intracellular bacteroids of the cockroach. Science, **101**: 336–7.

Buchner, P. 1930. Tier und Pflanze in Symbiose. Borntraeger, Berlin. 900 pp.

Dresner, E. 1950. The toxic effect of *Beauveria bassiana* (Bals.) Vuill., on insects. Jour. New York Ent. Soc., **58**: 269–78.

Glaser, R. W. 1946. Intracellular bacteroids in the cockroach (*Periplaneta americana* Linn.) Jour. Parasitol., **32**: 483–9.

Hall, I. M. 1952. Studies in the use of microorganisms in the control of the sod webworm. Hilgardia [In press.]

Jacobs, S. E. 1950. Bacteriological control of the flour moth, *Ephestia kuehniella* Z. Proc. Soc. Appl. Bact., **13**: 83–91.

Mansour, K. 1934. On the so-called symbiotic relationship between coleopterous insects and intracellular microorganisms. Quart. Jour. Microscop. Sci., **77**: 255–72.

Mattes, O. 1927. Parasitäre Krankheiten der Mehlmottenlarven und Versuche über ihre Verwend-

barkeit als biologische Bekämpfungsmittel. (Zugleich ein Beitrag zur Zytologie der Bakterien.) Gesell. f. Beford, Gesam. Naturw. Sitzber. Marburg, **62**: 381–417.

Musgrave, A. J., and J. J. Miller. 1951. A note on some preliminary observations on the effect of the antibiotic terramycin on insect symbiotic microorganisms. Canadian Ent., **83**: 343–5.

Steinhaus, E. A. 1939. Studies on the life and death of bacteria. I. The Senescent phase in aging cultures and the probable mechanisms involved. Jour. Bact., **38**: 249–61.

Steinhaus, E. A. 1951. Possible use of *Bacillus thuringiensis* Berliner as an aid in the biological control of the alfalfa caterpillar. Hilgardia, **20**: 359–81.

A Comparison of Aldrin, Dieldrin, Heptachlor and DDT for Control of Plague Vectors on the California Ground Squirrel[1]

RAYMOND E. RYCKMAN,[2] CHARLES T. AMES and CHESTER C. LINDT, *Department of Entomology, School of Tropical and Preventive Medicine, Loma Linda, California*

Plague was first suspected among wild rodents in the United States in 1903; diseased ground squirrels were shown to be the source of human cases in 1908. This disease has been recovered from rodents over 4,000 times in 15 western states (Link 1951).

In November, 1950 Colonel Robert Traub recommended that new chlorinated hydrocarbons be tested for the control of rodent fleas under field conditions. His data[3] (unpublished) indicated that aldrin and dieldrin were highly effective in controlling the trombiculid mite vector of scrub typhus in Malaya.

Smith (1951) tested 620 insecticides in the laboratory using the cat flea *Ctenocephalides felis* (Bouche) and the oriental rat flea *Xenopsylla cheopis* (Rothschild). Twenty-nine compounds were more effective than DDT. Outstanding toxicants reported were heptachlor, dieldrin, aldrin, BHC (95 per cent gamma isomer), chlordane and parathion.

PRELIMINARY FIELD SCREENING.—During 1951, field screening tests were conducted, by the authors, using eight chlorinated hydrocarbons (aldrin, dieldrin, heptachlor, toxaphene, lindane, chlordane, methoxychlor and DDT). These insecticides were dusted into 5,600 squirrel burrows. From the data obtained, there were indications that three insecticides should be given further study. These three were heptachlor, aldrin and dieldrin. DDT was used as a standard insecticide for comparison. Flea indices obtained in 1951 were as follows: heptachlor 2.0, aldrin 2.22, dieldrin 3.91 and DDT 90.85. The above results were obtained by dusting burrows with 3 per cent heptachlor, 1.5 per cent aldrin, 2 per cent dieldrin and 5 per cent DDT.

A COMPARISON OF APPLICATION METHODS.—An important aspect of any control program is to determine the most practical method of application. During 1952, dieldrin was applied by four methods: (a) sprayed on the surface of 11.5 acres at the rate of 1.04 pounds actual per acre, (b) dusted on the surface of 6 acres at the rate of 1.02 pounds actual per acre, (c) sprayed into 919 burrows with a Banta spray gun at the rate of 0.64 gram actual insecticide per burrow. Results obtained indicated that dieldrin was more effective as a spray than as a dust and that burrow application in each instance was superior to surface application. The flea index before treatment ranged from 39.7 fleas to 70.1 fleas; seasonal controls were at no time lower than 38.0 fleas per squirrel. The post-treatment index was: 0.48 flea per squirrel for burrows sprayed, 1.15 for surface spray application, 2.51 for burrows dusted and 4.87 for surface dusting. Dieldrin was selected as a standard insecticide in this experiment because of its residual action and toxicity to fleas on rodents under field conditions.

Seven dead squirrels and rabbits were recovered 4 days after dieldrin was sprayed on the 11.5 acre field mentioned above. Spraying or dusting the surface of pasture land with dieldrin is not recommended because of its toxic effect to mammals. However, in our experience, dusting

PAID PAPER.

[1] This research project was supported by a contract (DA-49-007-MD-185) from the Research and Development Board, Office of the Surgeon General, Department of The Army.

[2] The authors were assisted by Barbara A. Deem, Karl C. Fischer, Robert D. Lee and Dean Spencer.

[3] Robert Traub, Unpublished Manuscript.

or spraying burrows has never been a problem in pasture areas.

MECHANICAL AND ELECTRICAL BARRIERS.—Ecological and physical variables frequently arise in field studies which may tend to skew the data obtained.

Variables frequently encountered in field studies are:

1. Populations assumed to contain adequate rodents when research plans are formulated may subsequently prove inadequate for valid statistical analysis.
2. Differences in elevation, temperature, humidity and food of the hosts are frequently found which consequently influence the parasite population.
3. A differential of soil type, moisture and pH may affect the residual life of an insecticide.
4. Variation of the rodent population density frequently affects the parasite index.

To correct these situations, squirrel populations were enclosed in fields behind mechanical and electrical barriers. These animals were later used in studies concerned with the evaluation of heptachlor, aldrin, dieldrin and DDT as toxicants under field conditions.

The ground squirrel population in electrically fenced fields was 150 animals per acre. This was considerably higher than other squirrel populations studied. A high host index usually results in a higher parasite index per animal. An index of 90 fleas per squirrel was found to be the maximum in 19 squirrel populations studied over the past 2 years. In the fenced areas, the lowest index was 111.2 fleas per squirrel, and the highest was 318.0 fleas per animal. This high parasite index was, without doubt, due to an increased host density.

The electric fence was given critical tests relative to its application in conjunction with testing insecticides on parasitized rodents. Our studies have shown that the following significant advantages would seem to warrant continued use of this technique where insecticides are tested in the field on rodent parasites:

1. At the time insecticides were applied, the squirrel population per acre was uniform and high, resulting in a flea index from 111.2 to 318.05 per squirrel. This high parasite index was ideal for comparison of treated and untreated flea-infested rodent populations.
2. Squirrels were trapped in large numbers in a relatively short period of time. A sharp concise index may be obtained at any given time before or after treatment. Data obtained in this manner are more statistically valid.
3. Field variables were reduced to a minimum with respect to soil pH, temperature, humidity, host food, host index per unit of area, soil type and vegetation.
4. Insecticides were applied with greater accuracy because the terrain and burrows were more readily treated.
5. Squirrels did not enter treated areas from surrounding untreated areas.
6. Squirrels in the electrically fenced enclosures are not as readily removed by non-avian predators. In unenclosed fields, predators have been known to remove a relatively large segment of a rodent population during a short period of time.

During May and June, 1952, five units, each comprising an area of 44,100 square feet, were constructed and stocked with 750 California ground squirrels, *Citellus beecheyi* (Richardson). To date, January 1, 1953, after 9 months, none has escaped by climbing over the fence or by digging under it. These animals readily constructed large burrow systems, and surface runs became apparent in the vegetation. A detailed description of the electric fence and its construction will be published at a later date.

APPLICATION OF INSECTICIDES.—(A comparison of heptachlor, aldrin, dieldrin and DDT.)—Two and one-half per cent heptachlor, 2.5 per cent aldrin, 2 per cent dieldrin and 5 per cent DDT were applied within a 4-day interval at the rate of 30 grams of dust per burrow entrance. The dust was injected into the burrows with a cyanogas dust gun. Each gun was calibrated as to the amount of dust discharged per stroke. A four-man team systematically applied the insecticides to all burrows.

COLLECTION OF FIELD DATA.—One week to 10 days before dusting operations were conducted, control squirrels were taken from each of the five electrically fenced fields. Squirrels trapped for the parasite count were obtained in "live traps" and transported one-half mile to the laboratory. These animals were anesthetized with sodium nembutal at a dosage of 20 milligrams per 500 gram animal. The anesthetic was usually effective in ten to fifteen minutes after being administered and lasted for a duration of at least 30 minutes. During this time, most of the parasites were removed by a suction technique, and a final check was made with forceps to remove the remaining fleas. For each animal, a record card was made with the following information: (a) admission number, (b) date of capture,

Table 1.—A comparison of aldrin, dieldrin, heptachlor and DDT.

Column 1	2	3	4	5	6		
Insecticide and Application Rate	Index Before Treatment	Index After Treatment 3rd & 4th Days	Index After Treatment 13th–17th Days	Index After Treatment Approximate 35th Day	Distribution of Flea Species	Before Treatment	After Treatment
Heptachlor 2½% Dust. 30 gms. per entrance.	[1]20 111.2	34 0.058 [2]99.99%	30 0.23 99.79%	36 0.11 99.82%	20 *D. montanus* *H. anomalus* *E. gallinacea* Total....	100 22 858 1344 2224	 0 5 8 13
DDT 5% Dust. 30 gms. per entrance.	21 258.76	30 107.76 58.35%	32 74.31 71.28%	39 6.92 95.40%	21 *D. montanus* *H. anomalus* *E. gallinacea* Total....	101 46 816 4572 5434	 1 26 5854 5881
Dieldrin 2% Dust. 30 gms. per entrance.	20 318.05	30 0.93 98.70%	32 2.03 99.36%	38 0.02 99.91%	20 *D. montanus* *H. anomalus* *E. gallinacea* Total....	100 38 598 5725 6361	 5 7 82 94
No Insecticide Seasonal Control	20 171.35			31 99.67	20 *D. montanus* *H. anomalus* *E. gallinacea* Total....	31 23 276 3128 3427	 22 112 2956 3090
Aldrin 2½% Dust. 30 gms. per entrance.	20 128.05	30 0.13 99.89%	30 1.83 98.57%	40 0.07 99.91%	20 *D. montanus* *H. anomalus* *E. gallinacea* Total....	100 22 626 1913 2561	 0 7 55 62

[1] Upper left figure is the number of hosts from which data were derived.
[2] Lower right figure is the percentage of fleas killed.
Percentages in column 5 were derived from Abbott's formula.

(c) locality, (d) species of host and parasites, (e) sex and weight of host and (f) amount of anesthetic given. These animals were marked and returned to the fenced field from which they came. Marked animals were not retrapped for 30 days; however, an experiment was conducted which indicated that deparasitized squirrels acquired as many fleas in 10 days time as those which had never been deparasitized.

Results.—The pre-treatment flea index is recorded in column two of table 1. Seventy-two to 96 hours after treatment, ground squirrels were removed to determine the knock-down action of each insecticide (see column three of table 1). Additional animals were removed from the treated fields on approximately the fifteenth and thirty-fifth days after dusting (see columns four and five of table 1). Data obtained from squirrels trapped on the third, fifteenth and thirty-fifth days indicated that heptachlor, aldrin and dieldrin reduced the flea population to an index of 2.03 fleas per squirrel or less. This was in excess of 98 per cent control. During the same period of time, *i.e.*, third, fifteenth and thirty-fifth days, DDT gave the following controls respectively: 58.35 per cent, 71.28 per cent and 95.4 per cent. (See Table 1.) The DDT used in the experiment mentioned above was biologically assayed and found to be

highly active against a nonresistant strain of house flies.

SUMMARY.—Heptachlor, aldrin, dieldrin and DDT were tested as flea insecticides under field conditions. Field environmental factors were as nearly similar as possible in each test area with respect to temperature, humidity, elevation, soil type, host density and food eaten by the host. The flea index before dusting with the insecticides mentioned above ranged from 111.2 to 318.05 fleas per squirrel. Data obtained from squirrels removed on the third, fifteenth and thirty-fifth days indicated that heptachlor, aldrin and dieldrin reduced the flea population to 2.03 fleas per squirrel or less, this was in excess of 98 per cent control. During the same period of time, *i.e.*, the third, fifteenth and thirty-fifth days after treatment, DDT gave the following controls respectively: 58.35 per cent, 71.28 per cent and 95.4 per cent.

Dieldrin was applied by four standard methods in an attempt to control fleas on ground squirrels. Results obtained indicate that dieldrin was more effective as a spray than as a dust. Burrow treatment in each instance was superior to surface application. A method of constructing a mechanical and electrical barrier has been developed to effectively retain or exclude ground squirrels.

LITERATURE CITED

Link, Vernon B. 1951. Plague. Amer. Jour. Trop. Med. **31**(4): 452–7.
Smith, Carroll N. 1951. Compounds more toxic to fleas than DDT. Amer. Jour. Trop. Med. **31**(2): 252–6.

Ethylene Dibromide for Control of Black Hills Beetle[1]

C. L. MASSEY, R. D. CHISHOLM, and N. D. WYGANT, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[2]

Penetrating-oil solutions have been used for the control of certain bark beetles in the forests of western United States for many years. The development of such solutions reduced control costs and eliminated the hazards of burning infested material as a method of control. Salman (1938) reported the results of experiments with orthodichlorobenzene, paradichlorobenzene, crude flake naphthalene, and beta-naphthol dissolved in diesel oil to control several species of bark beetles in California. The infested trees were felled, limbed, and bucked, and the solution sprayed on the bark surface. Satisfactory mortality of the broods infesting Jeffrey, ponderosa, lodgepole, and sugar pine was obtained by the treatment when bark thickness did not exceed one-half inch. Gibson (1943) reported on the effectiveness of several oil solutions of fumigants on the mountain pine beetle infesting lodgepole and whitebark pine. He concluded that diesel oil-orthodichlorobenzene solutions combined low cost and control effectiveness to the greatest degree of any formula tested.

Since 1940 fuel-oil solutions of orthodichlorobenzene have been used extensively to control infestations of the Black Hills beetle. In 1947, in an effort to eliminate the costs of felling the trees before treating them, solutions of orthodichlorobenzene and fuel oil were applied to the bark of standing trees. The results were equal to those obtained in felled trees. Treating standing trees with a solution of 1 gallon of orthodichlorobenzene to 6 gallons of fuel oil has been the standard method of control since 1948.

Oil solutions of fumigants, while representing a tremendous advance over old methods of control, still had the disadvantage of being disagreeable to use and expensive. The cost not only included the purchase price of the oil at the tank car, but also its transportation into the forest by hand, pack animals, or jeeps. As a result of such disadvantages, tests were initiated in 1949 with water emulsions prepared from emulsifiable concentrates of various fumigants. Water is the most practical carrier of a toxicant where it can

[1] Because only part of this paper appeared (Vol. 45: 861–2) it is published in full here. Ed.
[2] In cooperation with the Colorado A. & M. College.

Table 1.—Survival of Black Hills beetle larvae in trees treated in the spring with emulsions of various fumigants.

Fumigant (Pounds per 5 Gallons of Emulsion)	Solvent	Per Cent of Water	Number of Living Insects per Square Foot of Bark
Ethylene dibromide:			
0	Fuel oil	60	23.0
1		60	1.1
2		60	.0
1		80	1.7
0	Stanisol	60	27.2
0.5		60	4.1
1		60	6.7
		70	1.5
		80	2.5
2		60	.8
		70	2.2
		80	.3
		90	.5
3		70	.3
		80	.1
		90	1.6
4		80	1.6
		90	2.3
0	Heavy	60	25.7
1	aromatic	60	4.0
2	naphtha	60	8.1
1		80	19.9
2		80	9.4
0	Solvesso 100	60	31.3
1		60	11.1
2		60	7.6
1		80	11.8
2		80	5.8
Dichloroethyl ether:			
1	Stanisol	80	29.5
2		80	32.9
4		80	18.4
8		80	20.4
Orthodichlorobenzene:			
2	Stanisol	80	23.4
4		80	38.0
8		80	61.3
Orthonitrochlorobenzene:			
1	Solvesso 100	80	37.9
2		80	30.1
4		80	40.0
Nitrobenzene:			
1	Stanisol	80	36.6
2		80	62.2
4		80	42.6
8		80	35.4
Check (untreated)			
0	0	0	60.2

be used, because it is present in most forested areas.

During the summer of 1949 several hundred standing ponderosa pines infested with the Black Hills beetle were treated with emulsions of ethylene dibromide in various solvents. The solvents tested were fuel oil, red engine oil, ethyl alcohol, and Stanisol, a cleaning solvent. Triton X-155, and alkyl phenoxy polyethoxy ethanol, was used as an emulsifier. Ten trees were treated with each formulation. The brood stage at time of treatment varied from mature larvae to callow adults.

A tabulation of the results of these tests revealed that approximately 2 pounds of ethylene dibromide in 5 gallons of emulsion was the minimum satisfactory dosage. Both Stanisol and fuel oil proved effective as solvents of the ethylene dibromide. Approximately 10 per cent of the solvent was needed for effective control.

To improve the formulation further and to determine the effectiveness of other fumigants and solvents, more extensive tests were made in 1950.

MATERIALS AND METHODS.—The fumigants, tested in emulsions and in solutions, included commercial grades of dichloroethyl ether, ethylene dibromide, nitrobenzine, orthodichlorobenzene, and orthonitrochlorobenzene. They were dissolved in No. 1 fuel oil, heavy aromatic naphtha (flash point 110° F.), Solvesso 100 (flash point 121° F.), and Stanisol.

The emulsifiable concentrates were prepared by mixing the fumigant, solvent, and emulsifiers. They were clear solutions that were readily emulsified by water. In all cases each gallon of concentrate contained 8 ounces of a mixture of Triton X-100, an alkylated aryl polyether alcohol, and Triton B-1956, a modified phthalic glycerol alkyd resin. A blend of three parts of Triton X-100 and five parts of Triton B-1956 was used in the concentrates containing No. 1 fuel oil, but a blend of equal weights was used in the other concentrates.

The first series of applications were made during May against the larval stages, and the second series during the latter part of June and early July against the pupal and adult stages. The spring, or larval, treatments were applied by means of a tank-type pressure sprayer powered by carbon dioxide. Bucket pumps were used to apply the summer, or pupal and adult, sprays. A 6-foot extension rod equipped with a No. 6 solid-stream nozzle aided in reaching the upper part of the infested stems. Approximately 3 gallons of material was applied to each tree, the exact amount depending on its size. The trees ranged from 8 to 24 inches in d.b.h.,

and each was treated until the insecticide began to run from the bark surface.

Five infested trees were treated with each formulation to a height of approximately 20 feet, and at least 3 weeks elapsed before they were sampled for insect survival. These samples were taken at breast height one-half-square foot in area on each of four sides of each tree. Only the live insects were counted. The mortality exhibited at this time determined the intensity of sampling needed in the treatment. If the mortality was sufficiently high to warrant further examination, the treated trees were felled and samples taken on opposite sides of each at heights of 1, 10, 15, and 18 feet. Untreated trees in the same area were sampled to determine the approximate mortality in the treated trees.

DISCUSSION OF RESULTS.—Tables 1 and 2 give the results with the emulsions, and table 3 with the solutions. Ethylene dibromide was the only effective fumigant tested in the emulsions. Dichloroethyl ether, orthodichlorobenzene, orthonitrochlorobenzene, and nitrobenzene in emulsions were unsatisfactory at the dosages tested. From the standpoint of cost and amount of toxicant used, ethylene dibromide was superior both to orthodichlorobenzene and to a 1:1 mixture of paradichlorobenzene and orthodichlorobenzene in No. 1 fuel oil.

One pound of ethylene dibromide in 5 gallons of fuel-oil emulsion was effective against all stages of the beetle. It is recommended, nevertheless, that 2 pounds of it be used in the formulation as a margin of safety. The higher dosage will insure satisfactory mortality of the pupae and adults, which are more resistant to the fumigant than the larvae. A reduction in this dosage may be possible after additional experimental work has been done to improve the formulation.

Both Stanisol and No. 1 fuel oil proved effective as solvents for the fumigant. No. 1 fuel oil, however, is more universally available and somewhat cheaper.

These tests indicate that 15 to 20 per cent of oil is necessary in the finished spray to obtain penetration of the bark. Therefore, it appears that the water should not exceed 80 per cent. For instance, emulsions containing 90 per cent of water were effective against the larvae but not against the pupae and adults.

Table 2.—Survival of Black Hills beetle pupae and adults in trees treated in the summer with emulsions of ethylene dibromide.

FUMIGANTS (POUNDS PER 5 GALLONS OF EMULSION)	SOLVENT	PER CENT OF WATER	LIVING INSECTS PER SQUARE FOOT OF BARK
Ethylene dibromide:			
0	Fuel Oil	80	25.2
1		80	.7
2		80	.0
0	Stanisol	60	14.2
½		60	12.8
1		60	4.6
2		60	.9
0		80	34.5
1		80	4.1
		90	5.8
2		80	.4
		90	10.2
3		90	2.7
Check (untreated)			
0	0	0	41.1

The cost of ingredients in oil solutions and emulsions of ethylene dibromide is about equal. However, a great saving in the cost of transportation can be effected when an emulsion is used. For example, a formulation that calls for 2 pounds of ethylene dibromide to be used in a mixture containing 80 per cent of water requires that only 1 gallon of stock, or one-fifth of the spray emulsion, be transported into the woods.

As a result of the tests made during 1949 and 1950, the following emulsifiable concentrate is suggested for field use in controlling broods of the Black Hills beetle: ethylene dibromide 2 lbs., emulsifier 8 oz., No. 1 fuel oil to make 1 gallon.

Table 3.—Survival of the Black Hills beetle in trees treated with solutions of various fumigants in No. 1 fuel oil. Larvae treated in the spring, and pupae and adults in the summer.

FUMIGANT (POUNDS PER 5 GALLONS OF SOLUTION)		NUMBER OF LIVING INSECTS PER SQUARE FOOT OF BARK AFTER	
		Spring Treatment	Summer Treatment
Ethylene dibromide	0.75	0.6	1.1
	1.5	.1	.0
	3	.1	.1
Orthodichlorobenzene	8	1.6	1.4
Orthodichlorobenzene paradichlorobenzene	4+ 4	—	.1
Check (untreated)	0	—	44.1

One gallon of this concentrate should be mixed with 4 gallons of water to make 5 gallons of emulsion.

Ethylene dibromide may also be used effectively in an oil solution at the rate of 1.5 pounds in 5 gallons.

LITERATURE CITED

Salman, K. A. 1938. Recent Experiments with Penetrating Oil Sprays for the Control of Bark Beetles. JOUR. ECON. ENT. 31(1): 119–23.

Gibson, Archie L. 1943. Penetrating Sprays to Control the Mountain Pine Beetle. JOUR. ECON. ENT. 36(3): 396–8.

Tobacco Hornworm Control with Organic Insecticides

NORMAN ALLEN,[1] C. R. HODGE,[2] A. R. HOPKINS,[2] and J. D. EARLY[1]

Because of the large size that hornworm larvae attain and the type of feeding injury that they inflict on the plant, they probably cause more damage to growing tobacco than any of the other insect pests of this crop in the United States. Haeussler (1952) has estimated that they cause an average annual loss of $84,073,000. Two species of hornworms attack tobacco. One is known as the tobacco hornworm, *Protoparce sexta* (Johan.), and the other as the tomato hornworm, *Protoparce quinquemaculata* (Haw.). The tobacco hornworm is the species of major importance in most of the flue-cured tobacco areas.

For many years lead arsenate has been used commonly for hornworm control. Lead arsenate has unusually good residual effectiveness. It is fairly safe to use on tobacco foliage and does not adversely affect the flavor or aroma of the finished product. However, since its lead and arsenic content constitutes a serious health hazard, State and Federal entomologists have for many years conducted experiments with a large number of insecticides in an effort to find one that would be just as effective without leaving dangerous residues on the tobacco. Marcovitch & Stanley (1937) and Allen *et al.* (1938) reported that cryolite was an effective hornworm insecticide, and some growers used it to replace lead arsenate for this purpose. Subsequent investigations disclosed, however, that a much heavier dosage of cryolite than of lead arsenate was required to give satisfactory hornworm control. Moreover, experience showed that it was not long-lasting, so that it was necessary to make more applications during the season. Because of these limitations cryolite has not been widely used by the tobacco growers.

Dominick (1950, 1951) and Allen *et al.* (1951) have reported encouraging results with TDE, toxaphene, and CS-708 against the tobacco hornworm. These three insecticides were also effective against the tomato hornworm on tobacco. The writers obtained outstanding control with endrin against the tobacco hornworm during 1952.

Some small-scale field experiments during the 3-year period 1950 to 1952 are described in this paper. The experiments were conducted at the South Carolina Pee Dee Agricultural Experiment Station at Florence, S. C.

PLAN OF THE EXPERIMENTS.—Two types of experiments were conducted each year. In one type the insecticides were applied to replicated small field plots of tobacco on the experiment station farm to determine their toxicity to hornworms and their possible effect on the flavor and aroma of the treated tobacco. In the other type the test materials were applied to severe infestations on growers' farms. In both types of experiments the plants were full-grown at the time of the tests and the infestation had been allowed to become severe so as to have as many larvae as possible for determining the value of the treatments.

In 1950 and 1951 the small-plot experiments were conducted on one fortieth

PAID PAPER.

[1] Norman Allen, entomologist, and J. D. Early, agent, U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine.

[2] Assistant entomologists, South Carolina Agricultural Experiment Station.

FIG. 1.—A mule-drawn traction sprayer equipped with an adjustable boom and a spray shield.

acre plots, arranged in randomized blocks so that there would be 4 replications for each treatment. Each plot was composed of 8 rows of tobacco 4 feet apart with the plants at intervals of 2 feet. The plots were separated at their ends by 14 feet of fallow and at their sides by 9 feet. In 1952 the plots were one-eightieth acre in area and contained 4 rows.

Experiments on growers' farms were conducted by locating a tobacco field that was severely infested with hornworms, dividing it into a number of equal-sized areas, and then replicating each treatment as many times as possible.

Dusts were applied by rotary hand dusters at 20 to 35 pounds per acre. Sprays were applied with small, mule-drawn traction sprayers equipped with an adjustable boom for treating different-sized plants and with a shield (Allen and Cox 1950) to protect the operator from the spray. A spray machine equipped in this manner is illustrated in figure 1. Where high-volume sprays were used. the output of the sprayer was about 75 gallons per acre, whereas for low-volume sprays the sprayer was equipped with T-jet nozzles and the output was about 18 gallons per acre.

The effectiveness of the insecticides was determined by counting the living hornworms on a definite number of plants per plot before treatment and the dead worms at intervals after treatment. To aid in counting the worms an especially designed cloth frame 24 by 28 inches, called a plant collar,[3] was placed about the base of each plant that was sampled (Fig. 2). Where dusts were used the plant collar was placed about the plants before the insecticide was applied, but where sprays were used it was placed there immediately after the sprayer had passed through the row middles of the plot.

EXPERIMENTS IN 1950.—The small-plot experiments consisted of two dust and three high-volume spray treatments. TDE and toxaphene were used in the dusts and TDE alone and mixtures of TDE or toxaphene plus parathion in the sprays.

The strengths and dosages and the results obtained 54 hours after an application are shown in table 1. All the treatments gave good hornworm control, but

FIG. 2.—Plant collar used about the base of a tobacco plant to aid in the recovery of treated larvae.

[3] Designed by J. U. Gilmore and W. A. Shands, entomologists, Bureau of Entomology and Plant Quarantine, to aid in the recovery of tobacco flea beetles that had been killed by insecticides.

Table 1.—Tobacco hornworm control obtained in 1950 with dusts and high-volume sprays applied to small field plots. Data based on 48 sampled plants per treatment and a final count after about 54 hours.

Material	Pounds of Active Ingredient Per Acre	Number of Larvae in Sample	Per Cent Reduction of Living Larvae	Per Cent of Dead Larvae
Dusts:				
TDE	3.0	212	100	80
Toxaphene	6.4	205	99	97
Sprays (wettable powder):				
TDE 50%	3.0	225	100	80
TDE 50% plus parathion 15%	3.0 plus 0.11	226	100	81
Toxaphene 40% plus parathion 15%	2.4 plus 0.11	220	99	81

counts made 24 to 30 hours after treatment showed that TDE was slower in killing the larvae when used alone than when parathion was added.

Since TDE appeared to be promising for hornworm control, it was tested as a dust, a high-volume spray, and as a low-volume spray on growers' farms during the latter part of the season. Undiluted cryolite as a dust and toxaphene in a dust and a spray were included in these experiments.

A brief summary of the results is given in table 2. TDE was effective in controlling hornworms, but, as in the small plots, when used alone as a dust it was slower in killing the larvae than where parathion had been added to the dust. The emulsion sprays at the rate of 2 pounds of active ingredient per acre caused some damage to maturing tobacco leaves. Consequently, for later tests the dosage was reduced to 1 pound per acre. At this dosage TDE was more effective than toxaphene.

Flavor and aroma studies on the cured tobacco made by two cigarette manufacturers at the end of the season showed that the toxaphene imparted an undesirable flavor and aroma to cigarettes. TDE did not appear to have any detrimental effect, except where a petroleum distillate was used as the solvent for the emulsifiable concentrate.

EXPERIMENTS IN 1951.—The small-plot experiment in 1951 was directed toward the further evaluation of TDE as a hornworm insecticide. Emulsifiable concentrates of TDE with standard solvent and with xylene as the solvent were compared. CS-708, with xylene as the solvent, was also tested. The results obtained from one application of these materials, given in table 3, show that all of them gave good hornworm control in 68 hours. However, counts made for the first 2 days showed that the TDE dust did not kill the hornworms so fast as the dust containing parathion in addition to TDE, or the TDE spray.

Each treatment was applied three times during the growing season, and samples of cured tobacco from these plots were subjected to flavor and aroma studies by two cigarette manufacturers. None of the treatments had any detrimental

Table 2.—Tobacco hornworm control obtained in 1950 with dusts and sprays applied to growers' farms. Data based on 25 to 40 sampled plants per treatment. Unless otherwise indicated, the final counts were made 54 hours after treatment.

Material	Pounds of Active Ingredient per Acre	Number of Tests	Number of Larvae in Sample	Per Cent Reduction of Living Larvae	Per Cent of Dead Larvae
Dusts:					
TDE	2.6	2	199	98	65
TDE plus parathion	1.9 plus 0.19	2	151	100	60
TDE[1]	4.2	1	72	100	36
Toxaphene[1]	5.4	2	150	100	65
Toxaphene plus parathion	2.9 plus 0.29	1	56	89	89
Undiluted cryolite (90% sodium fluoaluminate)	2.7	1	54	98	52
High-volume wettable-powder spray:					
TDE plus parathion	3.0 plus 0.11	1	117	100	76
Low-volume emulsion sprays:					
TDE	2.0	2	196	99	83
TDE	1.0	1	69	94	83
Toxaphene	2.0	2	175	96	86
Toxaphene	1.0	1	60	77	68

[1] Final count made after 4 days.

Table 3.—Tobacco hornworm control obtained in 1951 with dusts and low-volume emulsion sprays applied to small field plots. Data based on 80 sampled plants per treatment and a final count after about 68 hours.

Material	Pounds of Active Ingredient Per Acre	Number of Larvae in Sample	Per Cent Reduction of Living Larvae	Per Cent of Dead Larvae
Dusts:				
TDE	3.5	89	100	61
TDE plus parathion	1.4 plus 0.28	83	99	82
Sprays:				
CS-708	1.0	90	100	69
TDE (xylene)	1.0	100	100	72
TDE (Standard Solvent)	1.0	91	99	74

effect on the tobacco.

Several dusts and sprays were also tested on growers' farms during the latter part of the season. The most effective dusts were TDE alone, TDE plus parathion, CS-708, and endrin. Lead arsenate and Metacide dusts were fairly effective. High-volume sprays containing TDE and low-volume sprays containing TDE or CS-708 gave good control. Poor control was obtained with dusts containing ryania, ryania plus a synergist, and EPN plus methoxychlor.

EXPERIMENTS IN 1952.—Although TDE was found to control hornworms and it appeared to be satisfactory for use on tobacco, it was realized that an equally effective material with a more rapid killing action would be desirable. CS-708 appeared to be promising, but in speed of action it was not greatly different from TDE. Endrin as a 1 per cent dust, the only formulation of this insecticide available for testing in 1951, appeared to be very toxic for such a low concentration. Efforts in 1952 were therefore directed toward a further evaluation of endrin as a hornworm insecticide.

A small field-plot experiment failed because of a low infestation of hornworms in the field. Results of flavor and aroma evaluations of the tobacco samples are not yet available.

During the latter part of July a few plots of tobacco on the experiment station farm became severely infested with hornworms. These plots were used for a comparison of high-volume emulsion sprays containing endrin, TDE, and malathon. Endrin at 0.5 pound per acre killed a high percentage of the larvae within a short time and was more effective than 1 pound of TDE. Malathon at 0.5 pound per acre was relatively ineffective.

Endrin was tested in high-volume emulsion sprays in three experiments on growers' farms. In the first experiment 0.6 pound of endrin per acre killed the hornworms more quickly than 0.3 pound, but both dosages were effective. In the second experiment 0.6 pound of endrin was more effective than 1.5 pound of CS-708. The results of the third experiment are summarized in table 4. To determine the comparative speed of the different treatments in bringing the larvae under control, counts were made at frequent intervals after treatment. Endrin killed a high percentage of the hornworms within 8 hours and was much faster in killing the hornworms than TDE, CS-708, or CS-728.

DISCUSSION.—Although many of the treatments gave satisfactory hornworm control, it is emphasized that fairly long exposure to the insecticide was frequently necessary. To be of most value for control of tobacco hornworms an insecticide should kill more than 95 per cent of them in less than 3 days. One reason for this requirement is that a few large hornworms will ruin a tobacco field if left undisturbed for a few days. Another reason is that thundershowers are frequent in the flue-cured tobacco belt during the time that

Table 4.—Speed of action of several insecticides when applied as high-volume emulsion sprays for control of the tobacco hornworm on growers' farms. Data based on 25 plants per treatment.

Material	Pounds of Active Ingredient per Acre	Number of Larvae Treated	Per Cent Reduction in Living Hornworms After			Per Cent of Hornworms Dead After		
			3 hours	8 hours	36 hours	3 hours	8 hours	36 hours
Endrin	0.3	96	3	51	99	3	48	85
	0.6	111	6	71	99	6	71	94
TDE	1.0	102	0	40	93	0	15	59
CS-708	1.0	122	0	20	91	0	7	66
CS-708	1.0	87	0	1	82	0	1	48

hornworm larvae are most abundant and may reduce the effectiveness of a slow-acting insecticide by washing part of it off the leaves.

Of those insecticides tested prior to 1952, TDE was the most satisfactory; however, this material is slower acting than endrin in killing hornworm larvae. TDE dusts and sprays, particularly those containing parathion, which served as a control for associated infestations of hornworms and the green peach aphid, *Myzus persicae* (Sulz.) were used successfully by a large number of tobacco farmers in 1952. The fact that endrin gives a high kill in a short time may make it especially valuable for the control of hornworms, if it is otherwise satisfactory for use on tobacco.

The plant collars that were used in these experiments aided considerably in the recovery of the sick and dead hornworm larvae. In general, if an insecticide is highly toxic to hornworms and acts quickly, a high percentage of them can be recovered by the use of plant collars, since the hornworms do not move about much after the material is applied. Where an insecticide that is slow in killing the hornworms is used, the plant collars are less efficient, since the hornworms become sick and not only leave the tobacco plant but move over the rows and row middles. Larvae that are treated with less than a lethal dosage of some of the organic insecticides have convulsions for some time before they die.

SUMMARY.—Lead arsenate has long been the most widely used insecticide for control of the tobacco hornworm, *Protoparce sexta* (Johan.), but both lead and arsenic are cumulative poisons. Entomologists have therefore conducted experiments with a large number of insecticides to find one that would be toxic to the insect, safe for use on tobacco foliage, not impart an objectionable flavor and aroma to the finished product, and not contribute a serious health hazard.

In early experiments conducted at the South Carolina Pee Dee Agricultural Experiment Station, toxaphene was found to be very toxic to hornworm larvae, but it caused an objectionable flavor and aroma to cigarettes made from the treated tobacco. Experiments conducted during 1950, 1951, or 1952 showed TDE, endrin, CS-708, and Metacide to be promising for hornworm control. Poor control was secured with ryania plus a synergist, and EPN plus methoxychlor.

TDE dusts and sprays, which were tested most extensively, were found to be effective against hornworms, safe for use on tobacco foliage, and to have no adverse effect on the flavor and aroma of the tobacco (except in emulsifiable concentrates containing petroleum distillates).

Endrin was very toxic to hornworms when used as a 1-per cent dust in 1951. In further evaluation of endrin on small field plots as well as on growers' farms in 1952, an endrin emulsion applied as a high-volume spray not only killed a high percentage of hornworms but was much quicker in its lethal action than TDE, CS-708, or CS-728. However, a consideration of its use for the control of this insect must await the results of flavor and aroma studies on the cured product, as well as residue determinations, which are now underway.

LITERATURE CITED

Allen, Norman and Luther Cox. 1950. A spray shield for mule-drawn tobacco sprayers. S. C. Agr. Expt. Sta. Cir. 77.

Allen, Norman, J. W. Humphreys, and D. B. Lieux. 1938. Experiments with insecticides as a control for the tomato worm and flea beetles on tobacco. S. C. Agr. Expt. Sta. Ann. Rept. **51**:136–44.

Allen, Norman, C. R. Hodge and Luther Cox. 1951. New insecticides for hornworm control. S. C. Agr. Expt. Sta. Ann. Rept. **63**: 101.

Dominick, C. B. 1950. Control of hornworms on tobacco. JOUR. ECON. ENT. **43**: 221–2.

Dominick, C. B. 1951. Tests with insecticides for hornworm control on tobacco. JOUR. ECON. ENT. **44**: 539–41.

Haeussler, G. J. 1952. Insects as destroyers: Losses caused by insects. In U. S. Dept. Agr. Yearbook 1952, pp. 141–6.

Marcovitch, S. and W. W. Stanley. 1937. Control of tobacco insects in Tennessee. Tenn. Agr. Expt. Sta. Bul. **160**.

Weight Loss in Stored Wheat Caused by Insect Feeding[1]

GAILEN D. WHITE, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

It is often stated that the losses in stored grain caused by insect feeding amount to at least 5 per cent of the annual production. However, so far as is known to the writer, no detailed observations have been made on the weight loss during the developmental period of those species feeding within the kernels. Therefore, in connection with an investigation to develop survey methods for determining insect losses in stored grain, observations on the actual loss of weight in wheat during the developmental period of the rice weevil, *Sitophilus oryza* (L.), were conducted under controlled conditions.

METHODS.—With a standard grain *trier* a sample was drawn from a bin of newly harvested wheat in farm storage. This wheat was virtually free from insects, but so that no living insects would be present in the experimental grain, the sample was subjected to subfreezing temperatures for five days. The sample was then allowed to come to room temperature.

Fifteen subsamples were then drawn, ranging in weight from 14.1925 to 14.2020 grams each. The moisture content of the sample was 12.4 per cent, as indicated by a Steinlite moisture tester. Twenty adult female rice weevils, 2 to 3 weeks of age, were introduced in each of 10 of the subsamples. Five subsamples were reserved for uninfested checks. All the samples were then placed in a room maintaining a constant temperature of 80° F. and a relative humidity of 70 per cent. The weevils were permitted to oviposit in the grain for 2 days, and then removed.

The samples remained undisturbed in the constant-temperature room for one week after the weevils were introduced. At this time and at weekly intervals thereafter, the samples were weighed on an analytical balance. To prevent changes in the moisture content and temperature of the samples, all weighing was done in the same room. Any gain or loss in weight of the check samples was due to variation in moisture content and was used as a correction factor in determining losses in weight in the infested samples.

Emergence of the adult weevils began between the fourth and fifth weeks. They were removed from the samples daily to avoid losses in weight due to feeding. After 5 weeks emergence was complete and there were no further losses in weight. Radiographs[2] of the samples were made by the method outlined by Milner, *et al.* 1950. The number of infested kernels was found to total 2358.

RESULTS.—Through the period of observation there was loss in weight the first week after egg deposition, increase until the end of the fourth week, and then decrease slightly in the fifth week, during pupation and adult emergence (Fig. 1).

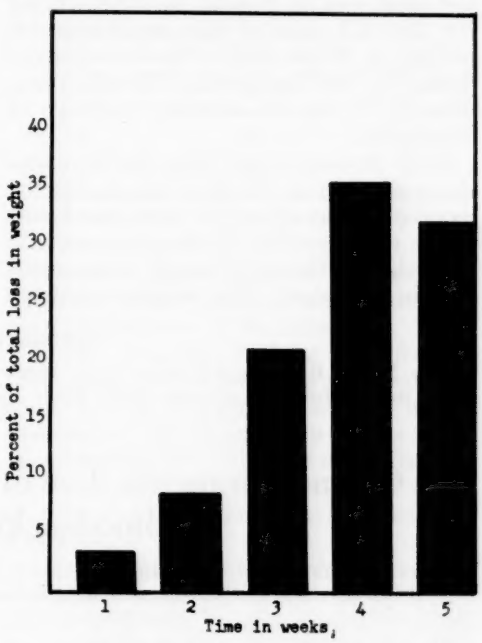


FIG. 1.—Weekly losses in weight of wheat infested with immature stages of the rice weevil.

The mean loss in weight per infested kernel was found to be 0.67 per cent after the first week of larval development, 2.36 per cent after the second week, 6.52 per cent after the third week, 13.59 per cent

[1] Presented at the meeting of the Association of Economic Entomologists at Philadelphia, Pa., December 15-18, 1952.

[2] Facilities for making radiographs were made available through the Departments of Physics and Milling Industry of Kansas State College.

after the fourth week, and 20.00 per cent upon the completion of emergence at the end of the fifth week. The weight of the refuse—*i.e.*, fecal matter, molted skins, pupal cases, and frass—left within the kernels after emergence was not determined. For this reason the total destruction of endosperm was greater than that indicated in these observations.

The average weight of newly emerged adult rice weevils was found to be 0.001225 gram, which constituted 3.76 per cent of the average weight of the whole kernel of wheat used in this work. The weight loss per kernel brought about by the development of the larva amounted to five times its adult weight.

The regression of per cent loss in weight of wheat on time is shown in figure 2. It may be noted that (1) 50 per cent of the total loss in weight occurred during the last 9.5 days of the developmental period; (2) 68 per cent of the loss occurred during the first four weeks of development when there was no outward evidence of infestation.

Only the net weight loss, due to oxidation-reduction as brought about by the metabolic processes of the immature forms of the rice weevil in its development and the weight of the adult weevil was considered in this work. This weight was dissipated in the form of heat, moisture, and gases, and constitutes a portion of the storage losses usually referred to by grain men as shrinkage.

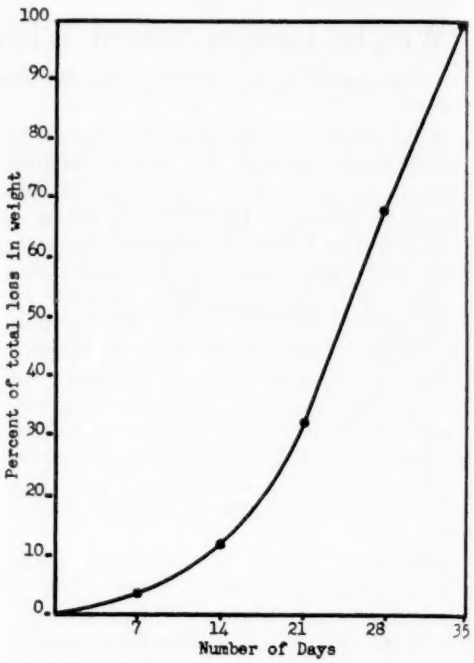


FIG. 2.—Regression of per cent of total loss in weight of wheat on time, during developmental period of the rice weevil.

LITERATURE CITED

Milner, M., M. R. Lee, and R. Katz. 1950. Application of X-ray technique to the detection of internal insect infestation of grain. JOUR. ECON. ENT. **43**(6) 933–5.

Chemotherapeutic Use of Insecticides for Control of Bloodsucking Insects[1,2]

ARTHUR W. LINDQUIST, A. R. ROTH, ROBERT A. HOFFMAN, and W. W. YATES, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*, and PAUL O. RITCHER, *Oregon State College*

The possibility of internal treatment of warm-blooded animals with chemicals to kill external parasites has been considered by entomologists for many years, but little research work has been reported. Knipling *et al.* (1948), who have conducted the most extensive investigations on this problem, treated rabbits with 33 chemicals, using body lice, mosquitoes, ear mites, and lone star ticks as test insects. Some of the indandione compounds were highly effective on lice, and BHC (gamma isomer) was effective on mosquitoes.

Chemotherapeutic treatment of animals for insect control might be advantageous in many situations, especially as a control of insect vectors in diseases such as anaplasmosis. The possibility of finding and developing chemicals or combinations of chemicals that are effective in killing insects and yet relatively harmless

[1] Presented at the meeting of the American Association of Economic Entomologists at Philadelphia, Pa., December 15–18, 1952.

[2] Published as Technical Paper No. 761 with the approval of the Director of the Oregon Agricultural Experiment Station. Contribution of the Department of Entomology of Oregon State College.

to the host appears to be reasonably good if intensive research is undertaken.

This paper describes studies on subcutaneous injections of several chemicals in mice and in cattle at Summer Lake, Oregon, in the summer of 1952. Five species of tabanids, three of mosquitoes, and horn flies were used as test insects.

TESTS WITH MICE.—*Methods.*—White mice weighing approximately 25 grams were treated subcutaneously with a 2-per cent solution of the insecticide in peanut oil at a dosage of approximately 25 mg. of the insecticide per kilogram of body weight (mg./K.), unless otherwise stated. One or two days after treatment the mice were confined tightly in cages of 0.75 inch mesh hardware cloth and exposed in quart fruit jars to the deer fly *Chrysops discalis* Will., or mosquitoes consisting primarily of *Aëdes dorsalis* (Meig.) but including a few specimens of *A. flavescens* (Müller). Length of exposure ranged up to 2 hours. Only those specimens showing clearly that blood had been taken were kept for observation of chemical effects. Usually 10 to 15 mosquitoes would take blood and 4 or 5 deer flies would become fully engorged with it. Mortalities of deer flies were recorded after 24 hours, but those of mosquitoes after 8 hours, since trouble was experienced in keeping the checks alive for 24 hours.

Mice were exposed daily to insects until no insect mortality was indicated or the mouse died. A high percentage of the mice died, probably because of the effect of the chemical, but daily handling and the loss of blood taken by the insects over several days no doubt contributed to their death.

In many instances there was slight leakage of the peanut oil solution at the site of injection, but special tests conducted by exposing insects to clipped hair demonstrated that kill of insects was not due to insecticide contamination of the hair.

RESULTS.—Owing to the large amount of data obtained, only a summary of the results is presented here. Typical results obtained with dieldrin, aldrin, and lindane are given in table 1.

Dieldrin and aldrin were effective in killing deer flies feeding on the mice several days after treatment. When seven mice were injected with dieldrin, all the deer flies were killed in each of 25 exposures over a period of 5 to 17 days. The longest period of insecticidal action was 16 days. All but one of the mice died.

Table 1.—Typical examples of mortality of mosquitoes and *Chrysops discalis* that had taken a blood meal on mice treated subcutaneously with dieldrin, aldrin, or lindane. Dosage 25 mg./K.

DAYS AFTER TREATMENT	PER CENT MORTALITY	
	Mosquitoes	*C. discalis*
	Dieldrin	
1	9	—
2	—	100
3	52	—
5	—	100
6	5	—
7	—	100
8	20	—
9[1]	—	100
	Aldrin	
1	10	—
2	—	100
3	50	—
5	—	100
6	28	—
7	—	100
8	30	—
9	—	100
	Lindane	
1	71	—
2	—	100
3	32	—
5	—	33
6	10	—
7	—	0
8	0	—

[1] Mouse died.

Aldrin was only slightly less effective than dieldrin. Thirteen days after treatment all the flies feeding on one mouse were killed. All except two of the eight mice treated died. In most cases the flies were seriously affected within 3 hours after taking blood, and death occurred in 6 to 8 hours.

The symptoms exhibited by dieldrin and aldrin were rapid movement of the wings, causing a buzzing sound, and unsteady walking. Flies feeding on untreated mice did not show any of these symptoms and 95 per cent of them lived for 24 or more hours.

Although dieldrin and aldrin gave good kills of deer flies, their effectiveness on mosquitoes was mediocre, the kill averaging about 50 per cent in 36 trials with both insecticides over a period of several days.

Heptachlor-injected mice lived only 3 to 7 days, but in several tests all the deer flies died. The mortality of mosquitoes

averaged somewhat higher with heptachlor than with dieldrin or aldrin.

Lindane used at 25, 50, and 75 mg./K. gave inconsistent and poor mortalities of deer flies and mosquitoes. Kill of these insects was seldom 100 per cent and some negative results were obtained. Only four of the 14 mice treated with lindane died—one each at the 25- and 75-mg. dosages and 2 at the 50-mg. dosage.

In order to determine whether the imbibed blood was toxic to other insects, deer flies engorged from mice injected with dieldrin and aldrin, and untreated mice were used in bioassay determinations. Ten days after the flies had fed, the following experiment was conducted. Their abdomens were cut off, ground, and placed in acetone at a rate of two insects per cubic centimeter; the acetone extracts were then tested on fourth-instar larvae of *Culex quinquefasciatus* Say. When 1 and 0.5 cc. of the acetone extracts were added to 100 cc. of water, extracts of flies exposed to dieldrin killed all mosquito larvae, extracts with aldrin killed 93 and 95 per cent, respectively, and the check killed no larvae in 48 hours.

A point of considerable importance is that little of the toxicant was excreted through the skin to contaminate the hair. It is, of course, possible that metabolites were excreted, but if so they were of such low toxicity that deer flies were not affected.

When injected into mice the following chemicals showed little or no toxicity to either deer flies or mosquitoes: DDT, TDE, methoxychlor, toxaphene, Q-137, the fluoro analog of DDT, the butyl analog of DDT, methyl-alpha, alpha-dimethylbenzyl sulfone, di-*n*-propyl sulfone, chloromethyl-*p*-chlorophenyl sulfone, chloromethyl-4-chlorophenyl sulfone, di-isobutyl sulfone, di-*p*-(phenoxyethoxyethyl-2-ethylhexoate) sulfone, di-*n*-sulfone, and chloromethylphenyl sulfone.

TESTS WITH CATTLE.—*Methods.*—The tests with cattle were run concurrently with the mouse tests. Dairy-type Jersey and Guernsey calves in medium condition, weighing from 150 to 250 pounds, were used. Lindane, aldrin, and dieldrin were ground in a mortar with peanut oil to give a 25-per cent concentration of the insecticide, and this mixture was injected under the loose skin posterior to the front leg and low on the side so that drainage could take place if the wound became infected. Observations showed only a slight leakage of the chemical, and this presented no problem of hair contamination. About 5 per cent of the chemical in the preparation was in solution and the remainder in the form of suspended particles. In two tests 5 per cent of aldrin or lindane in solution was used for a comparison with the suspensions described above. No difference in killing of insects was noted. No sterile techniques were employed and no infections occurred. Dieldrin and aldrin apparently affected the cattle, since they lost weight and appeared listless for 2 to 3 weeks. One lindane-injected animal (10 mg./K.) died 3 days after treatment and two (50 and 75 mg./K.) died 21 and 51 days after injection.

Usually 15 to 40 mosquitoes, 10 deer flies, and 3 to 5 of *Tabanus sonomensis* O. S., *T. productus* Hine, and *T. punctifer* O. S. were collected from each animal for each test. Engorged tabanids were obtained singly with a vial. *T. productus* was difficult to capture, because it bites only on the lower part of the leg. To permit mosquitoes to engorge on the animal a widemouthed quart jar containing about 50 specimens was held against the side of the calf. Two species of mosquitoes were used in the tests. *Aëdes dorsalis*, by far the most abundant species (99 per cent), and *flavescens*. The tabanid mortality was based on the 24-hour record. Eight-hour mortality records were made on the mosquitoes, since the checks did not survive 24-hour confinement in jars very well.

A total of 13 calves were treated and tested as follows: 1 each with allethrin (100 mg./K.), dieldrin, and heptachlor (both at 25 mg./K.), 2 with aldrin (25 mg./K.), and 8 with lindane (10 to 75 mg./K.).

Results.—Injections of dieldrin, aldrin, or heptachlor did not show much promise in killing insects, even though the first two compounds gave good results against deer flies when used on mice. Allethrin and heptachlor also were ineffective.

Lindane gave the best results on the greatest number of insects. Typical results are shown in table 2. A dosage of 50 mg./K. is apparently on the borderline of effectiveness.

Deer flies, primarily *Chrysops discalis*

Table 2.—Mortality of mosquitoes and tabanids that have fed on cattle treated subcutaneously with a 25-per cent suspension of lindane in peanut oil. Dosage 50 mg./K. followed in 3 days by 25 mg./K,

DAYS AFTER TREATMENT	MOSQUITOES	*Chrysops* SP.	*Tabanus sonomensis*	*Tabanus productus*
3	100	39	0	100
4	100	82	0	0
5	—	73	60	—
6	100	76	—	70
7	—	50	20	—
8	100	—	—	—
10	—	83	43	—
11	88	80	42	—
12	79	—	36	—
13	65	50	—	—
14	83	38	—	—
15	93	—	—	—
16	53	—	—	—
17	93	40	—	—
19	33	—	—	—
20	63	—	—	—
21	61	—	—	—
22	30	—	—	—
24	25	—	—	—
25	14	—	—	—

and a few *C. bishoppi* Bren., and *Tabanus productus* showed distinct symptoms 2 to 4 hours after feeding, and most of them were incapacitated in 8 hours. A few flies that were definitely affected by the chemical recovered in 24 hours. The fact that a 100-per cent mortality of flies did not occur very often indicated borderline dosages. The blood of the lindane-injected cattle showed toxicity to deer flies for several days, the mortality ranging from 40 to 100 per cent. The best record obtained was 80-per cent kill of deer flies 11 days after treatment of the animal.

Feeding on lindane-injected animals resulted in a good 8-hour mortality of mosquitoes, with toxic action indicated for several days. In two animals, treated with 50 and 75 mg./K., under observation for a long period 60- and 70-per cent mortality were recorded 18 and 21 days after treatment.

There were too few biting records of the other species of tabanids for reliable results, but it was definitely indicated that the lindane treatment was not very effective on *Tabanus sonomensis* and *punctifer*, both large species.

The average 24-hour mortality of deer flies feeding on untreated animals during the period of study was 5 per cent and the 8-hour records for mosquitoes averaged 11 per cent.

Precise data on horn flies, *Siphona irritans* (L.), were not obtained, but the following observations indicate that lindane-injected animals were effective in killing this species. When the first cattle were placed in a 5-acre pasture, a large horn fly population was present. The second day after the animals were injected, dead and affected horn flies were observed in the hair of the lindane-injected steer but not in those receiving aldrin or allethrin. On four consecutive mornings from 5 to 13 dead flies were removed. On the seventh day no horn flies either dead or alive, could be found on any of the treated or untreated animals, but they were present in great numbers in nearby pastures. During the next 30 days only an occasional fly was observed on the test animals. Two days before the work was terminated, approximately 1000 horn flies were collected and released on the experimental animals. The following morning live flies were observed on all animals except two that had been treated with lindane 10 days previously.

Numerous tests were made to determine whether hair of the cattle was toxic to insects, since the chemicals might be secreted in the oil around the hair. Hair clipped from different parts of the body early in the morning was exposed to deer flies, but very little if any toxicity could be demonstrated by hair from any of the treated cattle.

SUMMARY.—Studies on the chemotherapeutic use of insecticides for control of external parasites of warm-blooded animals were conducted at Summer Lake, Oregon, in 1952.

White mice treated subcutaneously with peanut oil solutions of several insecticides (25 mg./K. except with lindane) were exposed to the deer fly *Chrysops discalis* Will. and mosquitoes, primarily *Aëdes dorsalis* (Meig.). Mice injected with dieldrin killed all the deer flies within several days. With one mouse insecticidal action was recorded 16 days after treatment. Aldrin was slightly less effective than dieldrin when tested in the same manner. Neither insecticide gave such good results with mosquitoes (about 50-per cent kill in 36 trials over several days after treatment of the host), but heptachlor was more effective. Lindane gave

inconsistent and poor mortality on both deer flies and mosquitoes. Little or no toxicity to deer flies or mosquitoes was obtained with DDT, TDE, methoxychlor, toxaphene, Q-137, the fluoro analog of DDT, the butyl analog of DDT, and a group of sulfones.

Subcutaneous injections in cattle showed aldrin and dieldrin (25 mg./K.) to give poor kills of tabanids and mosquitoes. Allethrin at 100 mg./K. and heptachlor at 25 mg./K. were also comparatively ineffective. Lindane, however, at 50 and 75 mg./K. was toxic to mosquitoes up to 21 days after treatment. It was less effective against deer flies, 40- to 100-per cent mortality occurring for several days. Lindane was not very effective on other tabanids, but horn flies, *Siphona irritans* (L.), were eradicated in the experimental herd of animals.

LITERATURE CITED

Knipling, E. F., R. C. Bushland, F. H. Babers, G. H. Culpepper, and E. S. Raum. 1948. The evaluation of selected insecticides and drugs as chemotherapeutic agents against external blood sucking parasites. Jour. Parasitol. **34**(1): 55–70.

Control of Corn Earworm Attacking Sweet Corn in California[1]

O. G. BACON,[2] L. D. ANDERSON[3] and H. T. REYNOLDS[3,4]

Experiments conducted in 1950 by Anderson, Bacon, *et al.* (1951) in California demonstrated that satisfactory control of the corn earworm, *Heliothis armigera* (Hbn.), could be obtained with DDT sprays and dusts providing the applications were correctly timed and applied by proper methods. It was found that dust applications were most effective when applied by hand as individual ear treatments with a one inch stencil or similar paint brush. The most satisfactory sprays consisted of emulsions containing 0.75 per cent DDT and either five or ten per cent mineral oil. Best control with sprays resulted from individual ear applications although under the moderate earworm populations that existed in these tests fair control resulted with fixed nozzle boom applications.

The 1951 experiments were designed to further test methods of application developed in 1950 and to investigate some of the newer insecticides. Three series including 13 experiments were conducted from May to October at Indio and Riverside in southern California and at Arvin in the southern San Joaquin Valley. The more pertinent data obtained in these experiments are condensed in this paper.

MATERIALS AND FORMULATIONS.—The following eight insecticides were tested: DDT, CS-708, TDE, Q-137, compound

Table 1.—Control of corn earworm on Golden Cross Bantam sweet corn with various insecticide dusts applied as individual ear treatments with a stencil paint brush at the rate of 30 to 40 pounds per acre per application.

TREATMENT		WORM-FREE EARS PER 100 AT HARVEST		
Material	Per Cent	Test No. 1 Riverside[1]	Test No. 2 Riverside[2]	Test No. 3 Arvin[3]
DDT	5	90	94	97
Isodrin	1	86	92	97
Endrin	1	93	92	96
TDE	5	—	—	95
DDT	1	—	—	93
CS-708	1	80	90	93
Q-137	5	84	86	93
Q-137	10	84	87	—
Compound 1189	10	—	—	86
Compound 1189	5	—	—	81
Diluent (soapstone)	—	—	—	50
Untreated	—	6	4	5
LSD 5% level		7.7	8.5	7.8

[1] 3 applications at 3-day intervals.
[2] 4 applications at 3-day intervals.
[3] 3 applications at 4-day intervals.

[1] Paper presented at the meeting of the American Association of Economic Entomologists at Cincinnati, Ohio, December 1951.
[2] University of California, Berkeley.
[3] University of California Citrus Experiment Station, Riverside.
[4] Acknowledgment is made to T. O. Tuft and R. M. Hannibal of the Citrus Experiment Station, Riverside, Gordon L. Smith of the University of California, Berkeley, David N. Wright and Vernon E. Burton, Farm Advisors, Kern County, for assistance with the field tests; to Wallace Erwin of the University of California, Berkeley, for chemical analysis of plant samples; to Robert Bowlin of Indio and Don Barkley of Arvin for supplying sweet corn test plots, and to all others who aided in various ways with the different tests.

Table 2.—Control of corn earworm on Golden Cross Bantam sweet corn with several insecticide mineral oil emulsion sprays applied as individual ear treatments.

TREATMENT: 3 APPLICATIONS AT 4 DAY INTERVALS			
Insecticide		MINERAL OIL PER CENT[1]	WORM-FREE EARS PER 100
Material	Per Cent		
DDT[2]	0.75	5	100
DDT	0.75	5	98
DDT	0.75	0[3]	97
Q-137	0.75	5	95
Q-137[2]	0.75	5	92
TDE	0.75	5	92
Endrin	0.05	5	92
DDT	0.75	5[4]	91
Isodrin	0.05	5	85
Methoxychlor	0.75	5	82
Untreated	—	—	5
LSD 5% level			9.7

[1] The mineral oil was U.S.P. Grade, with Saybolt viscosity of 70 to 90 seconds.
[2] Insecticides dissolved in experimental solvent O-1172.
[3] 5 per cent O-1172 substituted for mineral oil.
[4] Sovaspray 100 oil substituted for the regular mineral oil.

1189,[5] endrin, isodrin, and methoxychlor. They were applied either as dusts or as emulsion sprays or as both dusts and emulsion sprays. The dust treatments used are shown in table 1 and the spray treatments are given in tables 2 and 3.

The dusts were either standard commercial preparations or experimental formulations supplied by various companies. Most of the sprays were formulated from commercial 25 per cent emulsifiable concentrates and U.S.P. grade mineral oil of 70 to 90 seconds Saybolt viscosity. Certain of the DDT and Q-137 emulsifiable concentrates were prepared by dissolving the technical materials in an experimental solvent.[6] These special formulations are indicated in table 2.

METHODS.—Three series of experiments were conducted. The first of these consisted of individual ear brush dust applications, the second, individual ear spray treatments and the third, fixed nozzle boom sprays. Each treatment was replicated either three or four times in each experiment. With the exception of the fixed nozzle boom sprays each replicate consisted of a single row either 100 or 200 feet long. The fixed nozzle spray plots consisted of double rows 100 or 200 feet long replicated three or four times.

The dusts were all applied by hand with a one inch stencil paint brush. For this treatment a one-gallon wide-mouthed tin can containing several pounds of dust was strapped around the operator's waist. The brush was pushed into the dust, then transferred with a slight but sudden thrust into the silk of the ear to be treated. Care was taken to strike the end of the ear squarely and to work the dust into the silk mass. Treatments were begun two to four days after the appearance of the first silks and were repeated at either 3 or 4 day intervals until three or four applications were made. Each silk mass was retreated each time applications were made even though considerable visible dust deposit remained from the previous dusting. This was necessary because the silks continue to grow outward from the ear until pollination is complete, thus, unless retreated, an area of silks is left free of insecticide immediately beyond the tip of the ear. Depending on the number of silks available for treatment, the dusts were applied at the rate of from 30 to 40 pounds per acre per application.

The sprays were applied with a small piston pump power sprayer mounted on the back of a garden tractor[7] equipped with a special high clearance rear axle.

Sprays were applied by fixed nozzle booms and as individual ear treatments by hand operated trigger guns. The gun used to apply the individual ear treatment was a modified painters spray gun[8] in which the outlet was tapped with one-eighth inch pipe threads to accommodate a Spray Systems one-eighth GG 1 nozzle. These trigger guns were operated at the end of 20 foot lead hoses attached to the sprayer. The guns were operated at a pressure of 90 pounds per square inch and from one to 1.5 cc. of spray was applied per ear per application. Three applications were made and were timed approximately the same as the brush dust treatments previously mentioned. Depending upon the number of ears to be treated from 6 to 8 gallons of spray were required to treat an acre of corn.

[5] 2,3,3a,4,5,6,7,7a,8,8-decachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene-1-one. Compound 1189, General Chemical Company.
[6] Solvent 0-1172 (di-2-ethyl-hexyl sebacate) manufactured by Rohm and Haas Co. for use as a plasticizer intermediate. It is a viscous clear liquid possessing little taste or odor.
[7] Bolens Huski Ridemaster manufactured by Bolens Products Division, Food Machinery and Chemical Corporation, Port Washington, Wisconsin.
[8] Binks Model 190.

Table 3.—Control of corn earworm obtained with various emulsion sprays applied with a fixed nozzle boom power sprayer.

Test[1] No.	Insecticide		Mineral Oil Per Cent	Gallons per Acre	Number of Applications	Worm-free Ears per 100 at Harvest
	Material	Per Cent				
1	DDT	0.75	10	50	4	94
	DDT	0.50	5	50	4	92
	DDT	0.75	10	25	4	80
	DDT	0.75	10	25	3	79
	DDT	0.75	10	25	2	74
	Untreated	—	—	—	—	43
	LSD 5% level					5
2	DDT	0.75	10	50	3	90
	DDT	0.50	5	50	3	79
	DDT	0.75	10	25	3	72
	Untreated	—	—	—	—	25
	LSD 5% level					10
3	DDT	0.75	10	50	3	92
					4	90
	DDT	0.50	10	50	3	85
					4	90
	DDT	0.50	5	50	3	85
					4	90
	DDT	0.75	10	25	3	71
					4	70
	Untreated	—	—	—	—	6
	LSD at 5%=5.6 for 3 applications—5.2 for 4 applications					
4	DDT	0.75	10	50	3	98
	Q-137	0.75	10	50	3	84
	Endrin	0.05	10	50	3	73
	Isodrin	0.05	10	50	3	73
	Untreated	—	—	—	—	8
	LSD at 5% level					11

[1] Test No. 1 and 2 at Indio; No. 3 at Riverside, and No. 4 at Arvin. The interval between applications was 4 days at Arvin and 3 days in the other 3 tests.

For the fixed nozzle boom spray applications, the equipment was modified to treat two rows of corn at a time. There were four spray nozzles per row, two for each side and they were adjusted to give complete coverage to 18 to 24 inches of the plant at ear height. One-quarter inch swivel-type Teejet[9] nozzles were used with No. 4 hollow-cone tips. The spray was applied at a pressure of 150 pounds per square inch and the machine was operated at a speed of approximately two miles per hour. The spray was applied at rates of 25 and 50 gallons per acre per application and two, three or four applications were made. The applications were spaced 3 days apart.

At harvest the ears were examined by pulling down the husks to expose the tips and the extent of infestation was determined. Fifty ears were examined in each replicate. The total number of ears examined for each treatment ranged from 150 to 200 depending upon the number of replicates. The ears were scored as wormy or clean. Only those ears completely free of damage were scored as clean.

Results.—*Individual ear brush dust treatments.*—The results of the individual ear brush dust applications are shown in table 1. All of the materials applied by this method resulted in from good to excellent control. DDT, endrin and isodrin received the best ratings and resulted in from 90 to 97 per cent clean ears for the DDT, 92 to 96 per cent clean for endrin and 86 to 97 per cent clean for isodrin compared with from 4 to 6 per cent clean in the untreated plots. It is interesting to note in the Arvin experiment that the dust diluent composed entirely of a

[9] Manufactured by Spraying Systems Co., Bellwood, Illinois.

ground soapstone resulted in 50 per cent clean ears as compared to 5 per cent clean in the untreated. Apparently heavy concentrations of dust in the silks act in some way to either kill the eggs or newly hatched larvae. Under the conditions of these experiments the number of applications and the spacing of the applications showed little or no differences in earworm control. Other work reported by Anderson *et al.* (1951) has shown that usually timing is very critical and that number of applications and treatment intervals are determined by the rate and evenness of silking. Treatments should begin within 2 to 3 days after appearance of the first silks and be repeated at 3 or 4 day intervals until three to five applications have been made.

In general the results obtained with dusts in the experiments were better than the results obtained by growers in comparable treatments. As an example, the remainder of the Arvin field in which the experimental plots were located received three applications of 5 per cent DDT dust by the brush method. Seven counts of 50 ears each were made in the area surrounding the experimental plots. The worm-free ears ranged from 78 to 96 per cent and averaged 87 per cent compared with an average of 97 per cent worm-free in the experimental plots.

Individual ear sprays.—The results obtained with individual ear sprays are indicated in table 2. As with the individual ear brush dust treatments all of the insecticides tested resulted in from good to excellent control. While the DDT formulations resulted in the greatest number of clean ears the differences were not significant from the control obtained with Q-137, TDE and endrin. Methoxychlor resulted in significantly poorer control than most of the other materials.

While endrin and isodrin did not result in as good control as some of the other materials it must be remembered that they were applied at much lower concentrations than the other insecticides. The finished sprays contained 1.5 ounces of endrin or isodrin as compared to 1.5 pounds of the other insecticides in 25 gallons of spray.

With individual ear spray applications spray burn has occasionally occurred on the ear husks when more than 1.5 to 2.0 cc. of spray was applied per ear or when the sprays were formulated from certain commercial insecticide concentrates. Apparently certain solvents used in the preparation of the concentrates are more phytotoxic than others. In these tests spray burn occurred on the husks in three of the treatments. The first instance was with the DDT formulation where Sovaspray 100 oil[10] was substituted for the U.S.P. grade mineral oil. Although U.S.P. grade mineral oil was used in all the other formulations, burning also occurred in the TDE and methoxychlor emulsion sprays. Apparently the solvents used in these formulations were to blame, as other formulations of these materials have been used on other occasions without injury.

The solvent *0-1172* was included to determine if this material would be safer from the plant injury standpoint than some of the other commercial solvents. In these experiments no injury to either pollination or to the plant tissues occurred where this solvent was used. It was used with and without mineral oil and many attempts were made to overdose ears in order to induce injury but none occurred.

Individual ear paint brush spray.—In three of the individual ear paint gun spray tests, additional individual ear treatments were made in which the liquid was applied by the paint brush dust application equipment. In these tests the DDT was used at 0.5 and 0.75 per cent and the mineral oil at 2.5, 5 and 10 per cent concentrations. From 2 to 3 cc. of solution was applied per ear. The gun and the brush spray methods were found to be equally effective. However, the brush spray method caused ear damage in some instances and further research is necessary on amount, time and concentration of applications by this method.

Fixed nozzle boom sprays.—The results of tests conducted with fixed nozzle sprays are shown in table 3. DDT was most extensively tested although in one experiment at Arvin Q-137, endrin and isodrin were also applied by this method. DDT was used at concentrations of 0.50 and 0.75 per cent in the finished spray and with 5 and 10 per cent mineral oil. Two, three and four applications were made at 25 and 50 gallons of spray per acre per application. Two early experiments at Indio were directed against rather light

[10] An isoparaffinic fraction in the approximate distillation range of kerosene, S.U.S. viscosity 33 at 100° F and a U.R. of 97.

UNIVERSITY OF WISCONSIN LIBRARIES

Table 4.—DDT residues on sweet corn resulting from various treatments.

Method of Application	Per Cent Concentration of Insecticide	Applications		DDT Residue P.P.M. on	
		Rate	Number	Leaves and Stalks	Unhusked Ears
Brush dust	5.0	30 P./A.	3	161.0	125.1
Individual ear spray	0.75	1.5–2 cc./ear	3	72.3	36.8
Fixed nozzle boom spray	0.75	50 G.P.A.	3	170.0	57.3
Airplane dust	10.0	40 P./A.	2	40.1	5.8

earworm populations. The later experiments at Riverside and Arvin were conducted against heavier populations although these would be considered on the border between a moderate and a heavy infestation. In all the tests 3 or 4 applications at 3 or 4 day intervals of 0.75 per cent DDT 10 per cent mineral oil emulsions applied at the rate of 50 gallons per acre per application resulted in the best control and gave from 90 to 98 per cent clean ears. DDT at 0.50 per cent concentration and with either 5 or 10 per cent mineral oil applied at 50 gallons per acre per application also resulted in excellent control, there being little difference between this and the preceding concentration. When these sprays were applied at the rate of 25 gallons per acre per application poor control resulted. Apparently 50 gallons of spray per acre per application is the minimum necessary to insure maximum control.

In the one test at Indio 2 applications at 25 gallons per acre was not significantly poorer than 3 applications and was barely poorer than 4 applications. In the other experiments there appeared to be little or no difference between three and four applications. Apparently at least 3 applications are necessary to insure maximum control.

In the Arvin experiment the Q-137 endrin and isodrin resulted in significantly poorer control than DDT. Endrin and isodrin, however, were applied at much lower concentrations than either the DDT or Q-137. With compounds endrin and isodrin only 3 ounces were applied per acre per application as compared to 3 pounds of DDT or Q-137. Some slight yellowing of the plants was observed in all plots treated with the fixed nozzle boom spray. This, however, was not considered to be particularly serious. The yellowing undoubtedly resulted from the rather large amounts of mineral oil deposited on the surface of the foliage.

Insecticide residues.—DDT residue analyses were run on corn plants from certain of the treatments in the Arvin experiments. This entire field had received 2 applications of 10 per cent DDT dust applied by air at the rate of 40 pounds per acre per application prior to silking to control tassel worms that were feeding upon the foliage and developing ears. This treatment was applied early so that there was little, if any, effect upon the worms that normally enter the ear and thereby did not effect the earworm control experiments but it did contaminate the plants from a residue standpoint. Samples were taken from brush dust, individual ear spray and fixed nozzle spray plots and from plots that had received no treatment other than the early airplane applications. Each sample consisted of 9 plants, three taken at random from each replicate. The samples were divided into two categories, leaves and stalks and whole unhusked ears. The samples were ground and mixed and a 500 gram random sample was taken for analysis. The samples were stripped with benzene and the residues in the benzene extract were determined by the Schechter-Haller method. The data are presented in table 4. It is readily seen that extremely large amounts of residue are left on the plants and whole ears as a result of the treatments. As mentioned earlier, all treatments were contaminated by the early aircraft applications. If this value is subtracted from the residue figures for the various treatments one can arrive at the approximate amount of DDT residue deposited by the later treatments.

The individual ear spray treatments resulted in the smallest DDT residues on either plants or ears. This would be expected since much less insecticide is used per acre than with any of the other treatments.

With the brush dust and fixed nozzle spray applications much larger amounts of insecticide are deposited on the plant and outer surface of the ears. These large DDT residues are of little consequence if one is considering only the ears destined for human consumption. Analyses carried out over the past several years involving various DDT formulations and methods of application have shown that there are either no residues or only insignificant amounts on the edible part of the ear. However, when the corn plants and the unmarketable ears are to be fed to livestock the residues present a serious problem.

Discussion.—During the 1950 and 1951 seasons, large acreages of sweet corn were treated by the brush method using 5 per cent DDT dust and no injury to pollination has been observed. This method does not require expensive equipment or technically trained operators. There are certain disadvantages to this method, however, that should be pointed out. Because brush dusting is an individual ear treatment it is time consuming and requires large crews of men to cover large acreages quickly. Timing of applications is critical. Under ordinary conditions this method of treatment should begin within one or two days after the appearance of the silk, and repeated applications should be made at no more than 3 day intervals for three or four applications. Brush dusting deposits extremely heavy amounts of dust on the tips of the ears. Large accumulations of dust frequently lodge in the axils of the leaves and tabs of the ears thus giving them an unsightly appearance. This dust deposit is largely washed off if the ears are pre-cooled in an ice water bath before packing. However some packers follow the practice of crating the ears before pre-cooling in the ice water bath. When this practice is followed the accumulation of dust remains caked in the silks.

Individual ear spraying has not attained as much favor with growers as has brush dusting. The cost of equipment is greater and if power equipment is used difficulty is often encountered in wet fields, thus interfering with proper irrigation schedules. Large crews are also required if extensive acreage is to be treated. If some of the operators lag behind the machine there is frequently a tendency for them to skip ears in an attempt to catch up with other operators in the crew. These untreated ears are difficult to detect thus complicating the job of supervision. If excessive amounts of sprays are applied there is danger of spray burn on the husks. The timing and number of applications with the individual ear spray method does not appear to be as critical as with the individual ear dust method. Better penetration and more thorough impregnation of the silk mass is obtained and if applications are carefully and thoroughly made excellent control of earworm results. The number of applications necessary to insure control varies from two to four depending upon the rate and uniformity of silking.

Fixed nozzle boom sprays have shown considerable promise under conditions of moderate infestations and under those conditions would be the most practical for the large grower to use. Under conditions of extremely severe infestations fixed nozzle sprays have not resulted in good control. The cost of equipment is high and difficulty is frequently encountered in wet fields. The advantages of this method lie in greater speed of application with less labor cost and less phytotoxicity hazards. With fixed nozzle spray applications timing is perhaps more critical than with any other method. The first application should be made as nearly as possible at the time of the emergence of the first silks.

Under conditions of extremely severe infestation an application just prior to silk emergence might be desirable. Repeated applications should be made at three or four day intervals depending on the rate of silking. A spray containing 0.75 per cent DDT and 10 per cent mineral oil has proven to be the most satisfactory. From three to four applications at 50 gallons per acre per application are necessary to insure effective control. The cost of material for the fixed nozzle boom treatments is greater than for the other methods of application; however, this is largely offset by the decrease in labor costs. A certain amount of yellowing of the corn plants has been observed where fixed nozzle sprays have been used. Large insecticide residues are deposited on the plants and outside surfaces of the ears with fixed nozzle applications.

SUMMARY.—Three series of tests were conducted comprising thirteen experi-

ments in which eight chlorinated hydrocarbon insecticides were compared. The insecticides were applied as dusts and as emulsion sprays. The dusts were applied to individual corn ears with a stencil paint brush. The sprays were applied with a power sprayer either as individual ear treatments or as fixed nozzle treatments. Three or four applications were made with each treatment, and the treatments were replicated three or four times. Ears were examined at harvest and scored as to damage by the corn earworm. The ears were graded as wormy or worm free even though many of those scored as wormy were marketable. Individual ear applications were most effective though fixed nozzle spray applications show considerable promise under conditions of moderate infestations. TDE, endrin, isodrin, Q-137 and CS-708 all resulted in promising earworm control though DDT is still the preferred insecticide.

Residue analyses were made on certain of the DDT treatments. Large DDT residues on the leaves, stalks and ears resulted from all treatments. The least amount of residue was found on plants and ears treated with the individual ear sprays.

LITERATURE CITED

Anderson, L. D., O. G. Bacon, H. T. Reynolds and J. E. Swift. 1951. Investigations of corn earworm control on sweet corn in California in 1950. JOUR. ECON. ENT. 44(6): 966–71.

Anderson, L. D., H. T. Reynolds, J. W. Hashe, and J. E. Swift. 1951. Studies on control of corn earworm on sweet corn in southern California in 1949. JOUR. ECON. ENT. 44(6): 905–9.

Action of Some Aliphatic Thiocyanates Against DDT-Resistant Strains of the House Fly

C. GUSTAFSON, JR., T. LIES, and T. WAGNER-JAUREGG, *From the Medicinal Chemistry Branch, Chemical Corps Medical Laboratories, Army Chemical Center, Md.*

Reports of increased resistance to DDT being shown by the common house fly and other insects give rise to a desire of finding insecticides which are effective against resistant strains. Since investigations have demonstrated that flies resistant to DDT will readily develop resistance to other chlorine-containing compounds, chlorine-free substances might be more promising in arriving at a solution to this interesting problem.

Thiocyanates have long been known to possess marked insecticidal properties (Brown 1951; Shephard 1947). Wilcoxon & Hartzell (1934, 1935) published several papers on the toxicity of alkyl thiocyanates to aphids and the mealy bug, among other insects. It was reported by Grove & Bovington (1946), that alkyl thiocyano acetates possess valuable knockdown properties when used against normal strains of the common house fly. One member of this group, *i.e.*, isobornyl thiocyano acetate, has found commercial use under the trade name "Thanite," A patent (Searle 1949) indicated the same insecticidal activity for thiocyano alkyl esters of lower aliphatic acids.

The present paper deals with the action of aliphatic thiocyanates against DDT-resistant strains of house flies. Comparative tests have been made with alkyl thiocyanates (RSCN), thiocyanohydrins (HOR SCN), and different ester types (RCOOR′SCN and ROCOR′SCN).

Though these substances are not as effective as DDT on a normal strain of house fly, their toxicity is approximately the same for the DDT-resistant strain as for the normal strain, which means a superiority of the thiocyanates over DDT in the case of DDT-resistant flies.

The thiocyanates used in this investigation are listed in table 1. The results of tests in which the substances were applied as contact insecticides against male and female DDT-resistant flies are given in table 2 and 3. The over-all picture shows three gradually differing groups:

(1) Ethyl and heptyl thiocyanate (No. 42A and 42B) have the least knockdown activity and toxicity.

(2) Somewhat more active are tetramethylene thiocyanohydrin (No. 44) and cyclohexene thiocyanohydrin (No. 46). Also, of the same order of magnitude is 2-thiocyano ethyl caproate (No. 41). 4-chloro butyl thiocyanate (No. 48) ranks

Table 1.—Properties of thiocyanates used in this investigation.

No.	Name and Formula	Mol. Wt.	Boiling Pt.	$n_D^{25°}$	%S Calculated	%S Found
14	Capryl β-thiocyano propionate $CH_3(CH_2)_4CH(CH_3)OCOCH_2CH_2SCN$	243.4	116–118°/0.43 mm.		13.2	13.29
16	Capryl thiocyano acetate $CH_3(CH_2)_4CH(CH_3)OCOCH_2SCN$	229.3	113–116°/0.35 mm.	1.4610	13.96	14.18
24	2-Thiocyano ethyl propionate $C_2H_5COOCH_2CH_2SCN$	159.0	98–102°/1 mm.	1.4694	20.14	20.03
34	2-Thiocyano ethyl isovalerate $i\text{-}C_4H_9COOCH_2CH_2SCN$	187.25	92–95°/0.2 mm.	1.4668	17.01	16.9
35	3-Thiocyano propyl butyrate $n\text{-}C_3H_7COOCH_2CH_2CH_2SCN$	187.25	105–110°/3 mm.	1.4681	17.01	18.1
37	3-Thiocyano propyl propionate $C_2H_5COOCH_2CH_2CH_2SCN$	173.2	88– 90°/0.065 mm.	1.4700	18.51	18.44
39	3-Thiocyano propyl crotonate $CH_3CH{:}CHCOOCH_2CH_2CH_2SCN$	185.23	120–121°/0.3–0.35 mm.	1.4921	17.3	17.2
40	4-Thiocyano butyl propionate $C_2H_5COOCH_2CH_2CH_2CH_2SCN$	187.25	100–103°/0.1–0.15 mm.	1.4705	17.01	17.05
44	Tetramethylene thiocyanohydrin $HOCH_2CH_2CH_2CH_2SCN$	131.17	103–105/0.2 mm.	1.5000	24.4	24.2
46	Cyclohexene thiocyanohydrin $o\text{-}HOC_6H_{11}SCN$	157.2	115–120°/0.3 mm.	1.5307	20.39	20.09
48	4-Chlorobutyl thiocyanate $ClCH_2CH_2CH_2CH_2SCN$	137.6	125–128°/1.1 mm.	1.5102	21.42	21.03
42A	Ethyl thiocyanate C_2H_5SCN	87.14	145/765 mm.	1.4637	36.8	
42B	Heptyl thiocyanate $C_7H_{15}SCN$	157.27	120–122°/15 mm.		21.8	

Table 2.—Knockdown activity of thiocyanates against DDT-resistant house flies.

		Unable to Fly After 10 Minutes Exposure							
		25%		50%		75%		100%	
No.	Formula	F	M	F	M	F	M	F	M
42A	C_2H_5SCN	>0.3	0.3						
42B	$n\text{-}C_7H_{15}SCN$	0.25		0.3		>0.3	0.27		0.3
41	$n\text{-}C_3H_{11}COO(CH_2)_2SCN$	0.18	0.1	0.27	0.15	>0.3	0.2–0.3		>0.3
44	$HO(CH_2)_4SCN$	0.2	0.15	0.32	0.25	>0.3	0.3		>0.3
46		0.05	0.05	0.27	0.2	>0.3	0.3		
39	$CH_3CH{:}CHCOO(CH_2)_3SCN$	0.05		0.1		>0.3	85% at 0.05		
48	$Cl(CH_2)_4SCN$					0.1	0.075	0.2	
37	$C_2H_5COO(CH_2)_3SCN$				0.1	0.1	0.2	0.15	>0.2
35	$n\text{-}C_3H_7COO(CH_2)_3SCN$						0.08	0.1	0.2
40	$C_2H_5COO(CH_2)_4SCN$			0.1–0.2		0.05	0.05		
24	$C_2H_5COO(CH_2)_2SCN$							0.05	0.05–0.1

F = Female. M = Male. The figures are expressed in mg. of thiocyanate per square inch.

Table 3.—Toxicity of thiocyanates for DDT-resistant house flies.

		Dead After 24 Hours Exposure							
		25%		50%		75%		100%	
No.	Formula	F	M	F	M	F	M	F	M
42A	C_2H_5SCN	>0.3	>0.3						
42B	$n\text{-}C_7H_{15}SCN$	>0.2	0.25	0.3	0.3	>0.3	>0.3		
41	$n\text{-}C_4H_{11}COOCH_2CH_2SCN$	0.15	0.13	0.2	0.17	0.3	0.2		>0.3
44	$HOCH_2CH_2CH_2CH_2SCN$		0.06	0.16	0.09	>0.3	0.15		0.3
39	$CH_3CH{=}CHCOOCH_2CH_2CH_2SCN$	0.1	0.12		0.15		0.18		0.2
46		0.08	0.08	0.16	0.12	0.25	(0.05) 0.18	0.3	(0.1) 0.28
35	$n\text{-}C_3H_7COOCH_2CH_2CH_2SCN$	0.08				0.2	0.16		0.2
48	$ClCH_2CH_2CH_2CH_2SCN$	0.11		0.15		0.17		0.3	0.2
37	$C_2H_5COOCH_2CH_2CH_2SCN$				0.12		0.18	0.2	>0.2
24	$C_2H_5COOCH_2CH_2SCN$		0.08	0.09	0.1	0.16	0.15	0.2	0.2
40	$C_2H_5COOCH_2CH_2CH_2CH_2SCN$	0.05		0.07		0.08	0.05	0.1	>0.2
14	$CH_3(CH_2)_4CH(CH_2)OCOCH_2CH_2SCN$	0.1	0.07		0.1		0.15	0.2	0.2
16	$CH_3(CH_2)_5CH(CH_3)OCOCH_2SCN$			0.07	0.07	0.1	0.1	0.2	0.2
	DDT	>>2	>>2						

F = Female. M = Male. The figures are expressed in mg. of thiocyanate per square inch.

approximately between this and the following group.

(3) The propionic and butyric acid esters of thiocyanohydrins of the formula $HO(CH_2)_nSCN$ ($n=2$, 3, 4) (No. 24, 35, 37, 40) combine the highest knockdown and killing capacities. An unsaturated homolog, the crotonic acid ester of propylene thiocyanohydrin (No. 39), can also be included here. The substances of this group are chemically stable and free from irritancy and objectionable odor when pure. The toxicity for mice was found to be relatively low. Hence this class of compounds, of all thiocyanates studied, might prove promising from the practical standpoint. One of the substances namely 4-thiocyano butyl propionate (No. 40), had been described at an earlier date in the patent mentioned before as effective against normal strains of flies.

Two thiocyano acid esters (No. 14 and 16) also showed high toxicity against DDT resistant flies (Table 3). These tests have been performed with later generations of the strain used for the experiments with the substances previously mentioned. Since these older generations seemed to be somewhat more sensitive towards thiocyanates the figures for these two substances given in table 3 should not be compared directly with the other values.

Certain aromatic thiocyanates have fungicidal properties (Genzer *et al.*, 1951). In order to get some information on the antifungal activities of the thiocyanates prepared for the present investigation, several of them were screened against *Aspergillus niger*, *Trichoderma* T-1, and *Penicillium luteum* by the Chemical Laboratories of the Inspection Equipment Agency, Army Chemical Center, Md. Two of the tested substances, namely, thiocyano ethyl isovalerate (No. 34) and capryl thiocyano acetate (No. 16), inhibited the growth of the tested fungi to a degree comparable to 2.2′-methylene-bis-(4-chloro-phenol), and are worthy of further consideration. Perhaps on more extensive investigation useful fungicides could be found among the aliphatic thiocyanates.

TEST PROCEDURES.—The normal strain of flies used was raised by Dr. F. M. Snyder and his assistants, of the Entomology Branch of the Chemical Corps Medical Laboratories. The DDT-resistant strain of house flies was developed by Dr. B. Sacktor of the same laboratory. The flies were collected, and the sexes separated within 24 hours of hatching. They were held for five to six days on a diet of powdered milk, sugar, and water before testing.

Because of a lack of facilities for employing more intricate methods of testing, petri dishes were used in the evaluation of the substances. Acetone solutions of the substances were made which contained one milligram of material per milliliter of solution. The dishes, whose area had been calculated, were coated with the necessary volume of the diluted acetone solutions to give the desired concentration of substance per square inch, and the acetone was allowed to evaporate, leaving behind a thin film of toxicant. Clean petri dishes were also prepared in which the flies were placed after exposure to the agent. Each such observation dish contained a vial filled with sugar water, stoppered with a cotton wick.

Anesthetization with CO_2 was necessary in order to transfer the flies from the holding cages to the testing dishes. The technique was developed to the point that the flies recovered from the carbon dioxide within 30 to 60 seconds after transfer to the petri dishes.

Twenty-five flies were used for each run. After being exposed for 10 minutes to the substance tested, the flies were then transferred to the clean observation dishes. Only in those cases where the flies remained active after the 10 minute exposure, being only slightly affected by the substance tested, was CO_2 used as an anesthetic to facilitate transfer to the observation dishes.

The knockdown activity of the substances was determined by counting the flies incapable of flight upon transfer to the observation dishes. The toxcity was determined by counting the number of dead flies in the observation dishes after 24 hours.

Most of the tests were repeated 2 or 3 times. The 25, 50, 75 and 100 per cent figures recorded in tables 2 and 3 are interpolated from the actual data obtained from the experiments with different concentration of thiocyanates. Where the results were in fair agreement an average value was employed. In the one case of larger deviations the values obtained are noted in parentheses; this apparent in-

consistency may possibly be due to a variation in the strain of flies.

The substances have been arranged in tables 2 and 3 roughly according to their increasing activity against female flies. In accordance with the findings of other investigators we observed that generally these were more resistant than males.

It should be noted, that the test method used gives only a general picture of the order of magnitude of the activity of the compounds. Space spray tests might provide a more realistic picture of their value as insecticides, but such equipment was not available for this investigation.

Toxicity of Thiocyanates for Warm-Blooded Animals: Mechanism of Action of Tetramethylene Thiocyanohydrin as a Poison.—Toxicity tests in mice were conducted by the Toxicology Branch of the Chemical Corps Medical Laboratories. When injected intravenously in propylene glycol solution No. 34 had an $LD_{50}=15$ mm³/kg., No. 24, 35 and 37 an $LD_{50}=30$ mm³/kg. The toxicity of No. 39 and 40 was found between these figures.

The LD_{50} for rabbits (i.v.) was 5–6 mg/kg for ethyl thiocyanate (No. 42A) and 6–7 mg/kg for tetramethylene thiocyanohydrin (No. 44). In the case of the latter, pharmacological tests were performed by Dr. B. McNamara and Carl W. Bender, of the Pharmacology Branch, Cml C Med. Labs. to learn something about the mode of action of this substance. It was expected that the toxicity would be due to the liberation of cyanide, as has been shown for other thiocyanates (V. Oettingen, 1936). The following experiments were made:

p-Amino-propiophenone (PAPP, 10 mg/kg, i.v.) was administered to six rabbits about 25 minutes prior to the previously determined LD_{100} dose (8 mg/kg, i.v.) of tetramethylene thiocyanohydrin; none of the rabbits died. The protective effect of PAPP (formation of methemoglobin), suggests that the toxicity of $HO(CH_2)_4$-SCN is similar to that produced by CN^-.

Tetramethylene thiocyanohydrin produced a rise of blood pressure in artificially respired cats. This is also suggestive of a cyanide-like action. i.e., hypertension resulting from interference with internal respiration despite adequate ventilation, or from stimulation of carotid body.

It was also possible to demonstrate, by qualitative analysis, the presence of cyanide ions in the blood of rabbits which had received high dosages of $HO(CH_2)_4$-SCN or of ethyl thiocyanate; the method of Gettler & Goldbaum (1947) was used in these tests.

Preparation of Compounds

Group I: RCOOR′SCN, ω-thiocyano alkyl esters of aliphatic esters, were prepared by a three step synthesis:

1. $R\,COOH+SOCl_2 \rightarrow RCOCl+SO_2+HCl$
2. $R\,COCl+HOR'Cl \rightarrow RCOOR'Cl+HCl$
3. $R\,COOR'Cl+KSCN \rightarrow RCOOR'SCN$

Group II: ROCOR′SCN, thiocyano acid esters, were prepared according to the procedure described by Grove & Bovington (1947).

Group III: HOR′SCN, Thiocyano hydrins. The methods of Wagner-Jauregg (1948b) and of Van Tamelen (1951) were used for their preparation. For the synthesis of 4-chloro butyl thiocyanate see Vogelsang, Wagner-Jauregg and Rebling (1950).

Ethyl and heptyl thiocyanate were purchased from the Eastman Kodak Co.

SUMMARY.—1. It was found that ethyl and heptyl thiocyanate have relatively low toxicity and knockdown activity for flies, although the lower alkyl thiocyanates are known to be very effective as fumigants for other insects (Brown 1951; Niefert 1925; Wagner-Jauregg 1948a). They are stable but have an objectionable odor.

2. The addition of an OH group to lower alkyl thiocyanates, in opposite position to the SCN group, increased its activity as a contact insecticide, in agreement with earlier observations; but this change in structure diminished the stability of the molecule, and several members of the series have repugnant odors.

3. Upon esterification of the hydroxyl group of thiocyanohydrins with lower aliphatic acids, substances are obtained which have marked properties of knockdown activity and toxicity for normal and DDT-resistant flies. The esters thus formed are stable, without undesirable odor and of relatively low toxicity for mice.

4. It has been shown that tetramethylene thiocyanohydrin liberates cyanide ions when injected into rabbits.

5. β-Thiocyano ethyl isovalerate and capryl thiocyano acetate have been found to possess antifungal activity.

ACKNOWLEDGMENT.—We are indebted to Dr. L. E. Chadwick, Entomology Branch, Chemical Corps Medical Laboratories, for the use of his laboratory for testing the insecticides, and to Mr. E. Fletcher for his assistance in conducting the tests.

LITERATURE CITED

Brown, A. W. A. 1951. "Insect Control by Chemicals." John Wiley, New York, N. Y., pp. 20, 92–3.
Genzer, J. D., C. P. Huttrer, and G. C. Van Wesson. 1951. Jour. Amer. Chem. Soc. **73**: 3159.
Gettler and Goldbaum. 1947. Analytical Chemistry **19**: 270.
Grove, T. F., and H. H. S. Bovington, 1947. Ann. of Appl. Biol. **34**: 113.
Niefert *et al.* 1925. Dept. Agr. Bulletin. 1313.
Oettingen, W. F. V. 1936. Am. J. Hyg. **18**: 310.
Searle, N. E. 1949. U. S. Patent 2,467,235 to E. I. Du Pont de Nemours Co. Apr. 12, 1949; *C. A.* **43**: 5153.
Shepard, H. H. 1947. "Chemistry and Toxicology of Insecticides," 8th Printing. Burgess Publishing Co., Minneapolis, Minn., pp. 240, 301–3.
Van Tamelen, E. E. 1951. Jour. Am. Chem. Soc. **73**: 3444.
Vogelsang, Wagner-Jauregg, and Rebling. 1950. Ann. **569**: 183.
Wagner-Jauregg, T. 1948a. Angew. Chemie **60**: 306.
Wagner-Jauregg, T. 1948b. Ann. **561**: 87.
Wilcoxon, and Hartzell. 1934. Cont. Boyce Thompson Institute **6**: 269, 1935, *ibid.*, **7**: 333, 497.

Determination of a Physiological Saline Solution for *Aedes aegypti* (L.)

RICHARD OLIVER HAYES

Physiological salt solutions have been studied for many different animals, and there have been some rather extensive investigations concerning normal salt solutions for insects. To date, no known physiological saline solution has been formulated for use with members of the Culicidae (Diptera). Such a solution could conceivably greatly reduce the rate of distortion and destruction of the insect's tissues and parasites which occurs during dissection.

The use of such a medium would be readily applicable in surveys involving the dissection of mosquitoes to determine their vector potentialities in diseases of medical and veterinary importance, and in studies on parasites utilizing the mosquito as their developmental host. It would find general application in morphological and physiological studies.

The determination of a satisfactory physiological saline solution for a member of the Culicidae was the purpose of this study. The osmotic pressure and the salt balance were the principal factors considered in the preparation of the perfusion medium.

Although references to studies concerning normal salt solutions for other animals have prevailed for many years, the literature concerning similar studies involving insects is relatively recent. Glaser (1927) grew hemolymph cells from the larvae of four species of moths in a modified Locke solution which he stated to be an isotonic salt mixture. In 1925, Eastham employed 0.60 and 0.75 per cent sodium chloride saline solutions for a study of malpighian tube movement in *Drosophila funebris* Fallen and *Calliphora erythrocephala* Meigen.

A modified Ringer's solution was used by Hobson (1928) in the study of the excised crop and esophageal contractions from *Dytiscus marginalis* Lec. In the same year, Levy investigated solutions in which to study heart preparations of the blowflies *Phormia regina* (Meigen) and *Calliphora erythrocephala* Meigen. He devised a complex salt solution and recorded the best results as based upon the synchronous beats of three parts of the heart.

In 1929 a 0.96 per cent saline solution for use in mitosis studies of sperm cells from the excised testes of the grasshopper *Chorthippus lineatus* Panz. was devised by Belar. This medium was later used by Silfer (1934) for an embryological study of *Melanoplus differentialis* (Thomas). Another saline solution was utilized in a study upon the cells of grasshoppers by Baumgartner & Payne (1931).

In studying blood cells of the American cockroach, *Periplaneta americana* (L.), Taylor (1935) used a 0.975 per cent salt solution. Yeager (1939) prepared a saline solution to be used with the American roach by varying the proportions of a solution described by Babers (1938) and Levy's solution until the steadiest state of heart beat was obtained with respect

to both rate and amplitude. Griffiths and Tauber (1940) devised a series of insect physiological solutions and tested these and several of the previously published types. They found a 1.5 per cent solution to maintain the strongest contractions for the longest periods of time. They based their conclusions upon the amount of muscular activity of the excised fore-gut of the roach.

A Locke solution buffered at pH 7.4 was used by Villes (1948) as the perfusion medium in his studies upon the larvae and the pupae of *Drosophila melanogaster* Meigen.

Table 1 gives the formulation of the physiological saline solutions described by the authors mentioned in this review.

MATERIALS AND METHODS.—The mosquito *Aëdes aegypti* (Linnaeus) was utilized as the test insect throughout the course of the study.

Table 1.—Insect physiological saline solutions.

AUTHOR	DATE	NaCl g/l	KCl g/l	$CaCl_2$ g/l	$NaHCO_3$[1] g/l
Baumgartner	1931	9.0	1.0	1.0	0.4[2]
Belar	1929	9.0	0.2	0.2	0.2
Eastham	1925	6.0			
Eastham	1925	7.5			
Glaser	1917	9.0	0.42	0.25	0.2[3]
Griffiths	1940	14.63	0.45	0.5	0.19
Hobson	1928	9.22	0.22	0.22	[4]
Levy	1928	9.0	0.71	0.46	0.17[5]
Taylor	1935	9.0	0.25	0.3	0.2
Villee	1948	9.0	0.4	0.2	0.2[6]
Yeager	1939	10.93	1.57	0.83	[7]

[1] Other g/l
[2] Dextrose—10.0
[3] Glucose—2.5
[4] Peptone—2.0
[5] NaH_2PO_4—0.01
[6] Glucose—2.5
[7] $MgCl_2$—0.17

The osmotic pressure was determined using the capillary tube method described by Halket (1913).

Drops of blood and of sodium chloride solution of known strength were alternately drawn into capillary tubes averaging approximately three inches in length. The capillary tubes had inside diameters of approximately 200 microns and outside diameters of about 340 microns. Each tube contained a number of drops of the two solutions alternating with each other, each drop being separated from the next one to it by an air space. Two terminal drops of the salt solution were provided in addition to the regular sequence of the fluids. When there were four or five drops of blood in the tube, its ends were fire-sealed. The tube was then fastened to a 1×3 inch microscope slide by depressing it across two horizontal clay strips which had been attached to the slide. The lengths of the drops were then measured with a micrometer eye piece in a compound microscope using a magnification of 20 diameters. The first and the last drops, which may have been slightly altered when the ends of the tube were sealed were not measured.

After the drops were measured, the tubes were placed in a holding cabinet maintaining a temperature of 37 degrees Centigrade. Twenty-four hours later the drops were remeasured. During this time interval the vapor pressure in the air spaces between the drops attained a state of equilibrium. In doing so the water vapor in the air condensed upon the surface of the drops of solution of the highest concentration, and those drops increased in size. By testing a series of known salt solutions against the mosquito blood it was possible to find which solution brought about no change in the sizes of the drops of blood. That solution was isotonic with the insect blood.

Fed and unfed male and female mosquitoes of various age groups were used as blood sources. The mosquitoes were anesthetized with carbon dioxide. Their wings and legs were then removed, and they were then dissected with the aid of a dissecting microscope having a magnification of 30 diameters. The first abdominal sternite was cut and a capillary tube was inserted into the body cavity. The clear body fluid then flowed into the tube with the aid of capillary attraction or was orally sucked into the tube by the investigator. Care was taken to insure that only the insect blood was collected and to prevent contamination with stomach contents and other debris. The drops of the known salt solution were introduced alternately into the capillary tube.

The proper salt balance was determined by measuring the survival time of mosquito spermatozoa in various complex salt solutions of the proper osmotic pressure and hydrogen ion concentration. The sperm were obtained by dissecting the male mosquitoes in the salt mixture to be tested. Minute insect pins mounted in applicator sticks were used to remove the male reproductive organs. The base of the common sperm duct was then cut, and the sperm dispersed throughout the saline solution. The sperm survival time was observed in uncovered drops of saline

and in drops under cover slips.

The hydrogen ion concentration of the body fluid was determined colorimetrically using a micro technique outlined by Patton[1] (1949). Bromthymol blue was the indicator utilized, and colors representing a pH range of 6.8 to 7.4, at intervals of 0.2 of a pH unit, were used. The hydrogen ion concentration of each colored solution was verified by checking it against a known standard on a Model G Beckman pH meter.

RESULTS.—Upon the basis of 72 tests 0.95 per cent salt solutions were observed to be isotonic with *Aedes aegypti* adult mosquitoes. No more variation was shown by males than by females. The lowest salt concentration tested was 0.7 per cent and the highest was 5.0 per cent.

The hydrogen ion concentration was observed to be 6.9 by the colorimetric method using bromthymol blue as the indicator.

A modified Belar's solution buffered at a pH of 6.9 was found to contain the most satisfactory salt balance and to maintain sperm activity longer than any of the other physiological salines tested. The longest sperm life in uncovered drops was 46 minutes whereas the longest survival time in covered drops was 120 minutes.

Upon the basis of the trials conducted a solution consisting of 9.0 grams of sodium chloride, 0.2 gram of calcium chloride, 0.2 gram of potassium chloride, and 0.1 gram of sodium bicarbonate per liter of distilled water was found to be the most satisfactory physiological saline solution for use with *Aedes aegypti*.

DISCUSSION AND CONCLUSION.—The use of Halket's capillary tube method for the determination of the osmotic pressure and of the time of spermatozoa survival as the criterion of salt balance have not been used previously in the formulation of physiological saline solutions.

The primary advantage of Halket's capillary tube technique is that it requires only a minimum of equipment. It also permits determination of the osmotic pressure of very small volumes of fluid and it is accurate to 0.1 per cent.

The principal disadvantage of this technique is that some mixing of the drops of blood and of the salt solution occurred due to the liquid films deposited on the sides of the tube during the movement of the drops.

Among the advantages of the spermatozoa survival criterion is that each sperm cell represents an individual test. Thus the results are not based upon the reactions of a single organ, but they depend upon the reactions of a large number of individual sperm cells. The movement or cessation of sperm activity is readily observed, and the time lapse between reduced activity and complete immobilization is quite short.

The possibility of sperm death due to mechanical injury or other factors is the primary limitation in the use of this particular criterion of salt balance.

The hydrogen ion concentration of the blood of most insects is nearly neutral. Frequently it is slightly acid and in some forms it has been found to be slightly alkaline. Sodium bicarbonate was used to buffer the saline solutions and thus maintain the proper pH value.

SUMMARY.—A review of saline solutions used for several insects is presented, and the methods used for the determination of a satisfactory physiological saline for the mosquito *Aedes aegypti* (Linnaeus) is given. A modified Belar's saline solution consisting of: 9.0 grams of sodium chloride, 0.2 gram of both calcium and potassium chloride, and 0.1 gram of sodium bicarbonate per liter of distilled water was found to be the most satisfactory saline tested.

[1] Patton, R. L., 1949. Insect physiology syllabus. Cornell Univ., Ithaca, N. Y., 3rd Rev., 229 pp. Unpublished.

LITERATURE CITED

Baldes, E. J., and A. F. Johnson. 1939. The thermoelectric osmometer; its construction and use. Biodynamica 2(47): 1–11.

Babers, F. H. 1938. An analysis of the blood of the sixth-instar southern armyworm, *Prodenia eridania*. Jour. Agr. Res. 57: 697–706.

Baumgartner, W. J., and M. S. Payne. 1931. Intravitam technique used in studies on the living cells of grasshopper. Jour. Expt. Zool. 59: 359–84.

Belar, K. 1929. Beitrage zur kansalanalyse der mitose. II. Untersuchungen an den spermatocyten von *Chorthippus* (*Stenobothrus*) *lineatus* Panz. Arch. Ent. w. Mech. 118: 359–484.

Eastham, L. 1925. Peristalsis of the malpighian tubules of Diptera, preliminary account. Quar. Jour. Micro. Sci. 69: 385.

Glaser, R. W. 1917. The growth of insect blood cells in vitro. Psyche **24:** 1–7.
Griffiths, J. T., Jr., and O. E. Tauber. 1940. Motility of the excised fore-gut of *Periplaneta americana* (Orthoptera) in various salt solutions. Iowa St. Col. Jour. Sci. **14:** 393–404.
Halket, A. D. 1913. On various methods for determining osmotic pressures. New Phytologist **12:** 164–76.
Hobson, A. D. 1928. The effect of electrolytes on the muscle of the fore-gut of *Dytiscus marginalis* with special reference to the action of potassium. Brit. Jour. Expt. Biol. **5:** 385–93.
Levy, R. 1928. Fonctionement du vaisseau dorsal de la larve de mouche en milieu artificiel. Comptes Rendus, Soc. Biol. **99:** 1482.
Silfer, E. H. 1934. Insect development. VI. The behavior of grasshopper embryos in an anisotonic, balanced salt solution. Jour. Expt. Zool. **67:** 137–57.
Taylor, A. 1935. Experimentally induced changes in the cell complex of the blood of *Periplaneta americana*. Ann. Ent. Soc. Amer. **28:** 135–45.
Villee, C. A. 1948. Studies in biochemical genetics in *Drosophila*. Jour. Gen. Physiol. **31:** 337–45.
Yeager, J. G. 1939. Electrical stimulation of isolated heart preparations from *Periplaneta americana*. Jour. Agr. Res. **59:** 122–3.

Laboratory Culture of the Pink Bollworm on Chemically Defined Media

HERMAN F. BECKMAN,[1,2] SARA M. BRUCKART,[1] and RAYMOND REISER[2]

One of the greatest obstacles to research in insect nutrition and physiology has been the inability to rear and study the various stages under controlled conditions, including diet, in the laboratory. A number of insects have been reared on artificial media (Beck *et al.* 1949, Fraenkel & Blewett 1946, Noland *et al.* 1950), but with few exceptions this has been accomplished by the use of a crude diet. No record was found of an oligophagous insect having been reared under controlled conditions on a chemically defined diet.

The pink bollworm, *Pectinophora gossypiella* (Saund.), may be considered as an oligophagous insect, since it attacks only plants belonging to the family Malvaceae. It is one of the most important pests of cotton and was selected for this study in the hope that an exact knowledge of its nutritional requirements and physiological peculiarities would be obtained which might provide new avenues leading toward practical methods of control. Another advantage would be to have a constant supply of controlled specimens for laboratory study.

A review of the literature on insect nutrition gave clues to the essential nutrients for the insect diet. The protein requirements of insects have been demonstrated by Noland and Baumann (1951), who have also shown the differences in nutritive value of various proteins. The requirement for fat as such, other than as a source of energy, has never been demonstrated. However, linoleic and arachidonic acids have been demonstrated to be essential nutrients in the diet of certain moths (Fraenkel and Blewett 1945, 1947). Fat-soluble substances, such as alpha-tocopherol and sterols, have also been found necessary for normal growth (Fraenkel & Blewett 1944, Hobson 1935). It has been shown that vitamins A, D, and C are not needed for normal growth of insects (Bowers & McCoy 1940; Day 1949; Trager 1947).

Of the water-soluble vitamins necessary in insect nutrition, those of the B group are especially important (Fraenkel & Blewett 1942, 1944, 1947; Tatum 1941). These requirements may be satisfied in part by internal symbiotic microorganisms.

EXPERIMENTAL.—*Preparation of medium*—The medium found to be the most successful for the rearing of pink bollworms is a modified chick ration having egg albumin as the protein constituent (Reiser *et al.* 1951). The use of crystalline vitamins and dextrose makes this ration almost completely water-soluble. Heating in boiling water coagulates the albumin and a homogeneous solid is formed. The composition of the medium is as follows:

Bulk constituents

	Per Cent
Dextrose	49
Egg albumin	25

[1] U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine.
[2] Texas Agricultural Experiment Station.

Cottonseed oil	20
Salts 4	5
Cholesterol	1
B_{12} concentrate[1]	0.6
Choline chloride	0.25
Inositol	0.125
Water-soluble vitamins	
	mg./kg.
Niacin	70
Calcium pantothenate	25
Pyridoxine hydrochloride	8
Riboflavin	8
Thiamin hydrochloride	6
p-Aminobenzoic acid	8
Folic acid	2.5
Biotin	0.25
Fat-soluble vitamins	
	mg./kg.
Mixed tocopherols[2]	10 gm./kg.
Menadione	15
Carotene	330
Vitamin D_3	0.08

[1] B12, 12.5 mg. per pound.
[2] 170 mg. of D-tocopherol per gram.

The composition of salts 4, according to Hegsted *et al.* (1941), is as follows:

	Grams
$CaCO_3$	1200.0
K_2HPO_4	1290.0
$CaHPO_4 \cdot 2H_2O$	300.0
$MgSO_4 \cdot 7H_2O$	408.0
NaCl	670.0
$FeC_6H_5O_7 \cdot 6H_2O$	110.0
KI	3.2
$MnSO_4 \cdot 4H_2O$	20.0
$ZnCl_2$	1.0
$CuSO_4 \cdot 5H_2O$	1.2

n-Butyl parahydroxybenzoate is used to inhibit mold formation. It is dissolved in ethyl alcohol in the proportion of 1 gram per 10 ml.

In the preparation of the medium, 150 ml. of distilled water is added in small portions to 100 grams of the dry material, and mixed well with each addition. Two ml. of the mold-inhibitor solution is then added slowly with stirring. About 150 mg. of purified cotton linters[3] is placed in the bottoms of vials (15 by 45 mm.), and the medium is added until the linters are just saturated. It is not known whether these linters contribute some unknown nutrient to the medium. The vials are plugged with absorbent cotton, placed in a rack, and lowered into a boiling water bath for 10 minutes to coagulate the egg albumin. The rack is then removed and cooled in water. When cool, the vials are inverted until inoculated.

Preparation of eggs for inoculation.—Pink bollworm eggs are placed in a 0.1 per cent solution of mercuric chloride for 4 minutes, after which they are dipped in a physiological saline solution, using a sterile camel's hair brush, and immediately transferred to the wall of a vial just above the medium. Usually five eggs are put into each vial. The eggs are then incubated at 26°–29° C. High humidity is provided by keeping a large shallow container of water in the incubator.

RESULTS.—The results of experiments in which larvae lived past the first instar are summarized in table 1. In the first 10 experiments the ration, which contained only 1 per cent of fat, supported growth only as far as the pupal stage. In one of

[3] Obtained from the Buckeye Cotton Oil Company, Memphis, Tenn.

Table 1.—Results of laboratory experiments to culture the pink bollworm on a chemically defined diet.

Experiment No.	Diet		Number of Eggs		Number of Pink Bollworm Larvae to Reach				
	Linters	Per Cent of Fat	Total	To Hatch	Second Instar	Third Instar	Fourth Instar	Pupa	Adult
1	+	1	333	95	4	3	1	1	0
2	+	1	186	54	2	2	1	1	0
3	+	1	161	70	1	1	0	0	0
4	−	1	236	1	1	1	1	1	0
5	+	1	629	356	37	21	10	4	3
6	−	1	313	238	4	1	0	0	0
7	−	1	47	47	7	3	1[1]	0	0
8	−	1	147	115	8	3	2	2	0
9	+	1	274	108	12	0	0	0	0
10	+	1	328	256	13	4	0	0	0
11	+	5	126	65	4	2	1	1	1
12	+	6	70	9	1	1	1	1	1
13	+	10	79	70	17	5	4	2[2]	1
14	+	10	122	77	9	4	1[1]	0	0
15	+	20	158	97	24	17	7[3]	6	6
Total	—	—	3109	1658	144	68	30	19	12

[1] Long-cycle larvae were in the fourth instar for more than 2 months.
[2] 1 killed by mold.
[3] 1 a long-cycle larva.

these experiments the bollworms reaching the fourth instar were transferred to a medium containing 20 per cent of fat; of four purpae developing, three became adults. Moths that failed to emerge completely were found to have malformed wings and to be deficient in wing scales. This essential fatty acid deficiency symptom has been described by Fraenkel & Blewett (1947).

In experiments 11 through 15 the fat content was increased to 5 per cent or more, and normal adult moths emerged.

DISCUSSION.—In 25 earlier experiments few eggs hatched and the larvae died immediately. In these experiments, the principle of soaking the medium into linters had not been developed, nor had the optimum proportions of the constituents been determined. Furthermore, the larvae were incubated with no effort to control the moisture content. As the medium dried, larval growth was definitely slowed down, but on the addition of water was again accelerated.

In the present experiments increases in fat level were at the expense of dextrose. The fat content of the medium was tried at 1, 5, 6, 10, and 20 per cent. A medium containing 1 per cent of fat supported slow larval growth and produced four abnormal adults. Media containing 5 and 10 per cent of fat supported more rapid growth and produced a few adults, but the most rapid growth and the largest number of adults were noted with a medium containing 20 per cent of fat. The advantage of fat levels above 5 per cent was probably due to the physical properties the fat imparted to the medium rather than any added nutritive quality, although it is recalled that the pink bollworm larvae do develop in the maturing cotton seeds.

Efforts to achieve a more desirable texture as well as to introduce some bulk into the diet led to the use of purified cotton linters. It had been noted that media without cotton linters failed to attract the larvae, but that the cotton plug in the vial did attract them. The linters provided a medium with air spaces, attracted the larvae, and permitted them to tunnel. Fourth-instar larvae have been noted to feed upon the cotton plugs and have appeared also to consume the linters.

Other inert materials were tested to supply desirable texture, such as powdered cellulose, methyl cellulose, asbestos, glass wool, Fiberfrax,[4] wood pulp, and celite. With each the medium dried out too quickly or the texture of the coagulum was not desirable.

In these experiments it was found that the moisture content of the medium should be kept constant. If dessication becomes evident, a few drops of water should be added. After pupae form, emergence of the adults may be hastened by bathing the pupal case with a few drops of water.

The medium and conditions described herein may still not be the optimum, since even the shortest time from egg to adult was longer than occurs in the field. Furthermore, reproduction has not been obtained in the laboratory.

An incubation temperature of 26 to 29° C. has been found to be satisfactory for the development of larvae and pupae. An incubation temperature of 35° C., while permitting an occasional egg to hatch, was always fatal to the newly hatched larvae.

Although a high and fairly constant humidity has been maintained in the incubator by shallow pans of water, keeping the air circulating within the incubator also has helped to provide the desired humidity.

By controlled handling of the eggs from the time of oviposition it should be possible to increase the hatchability and decrease the mortality during the first instar, and possibly during the other instars, the pupal stage, and at emergence. Moths are now being induced to oviposit in the laboratory.

How much the hatchability can be increased and the mortality of the larvae decreased has been difficult to estimate. Loftin *et al.* (1921) found that over 90 per cent of pink bollworm eggs never produced adults in laboratory experiments, using green bolls on stems stuck into a vial of water. Under field conditions as high as 85 per cent of the eggs laid did not produce adults. However, under controlled and almost sterile conditions in the laboratory it should be possible to increase this efficiency greatly.

In spite of possible physical damage to the eggs, however, the ration and cultural conditions used have proved adequate to allow some insects to develop from eggs to adults.

[4] A product of the Carborundrum Company, Perth Amboy, N. J.

LITERATURE CITED

Beck, S. D., J. H. Lilly, and J. F. Stauffer. 1949. Nutrition of the European corn borer, *Pyrausta nubilalis* (Hbn.). Ann. Ent. Soc. Amer. **42**(4): 483.

Bowers, R. E., and C. M. McCoy. 1940. Insect life without vitamin A. Science **92**: 291.

Day, M. F. 1949. Vitamin C in insects. Austral. Jour. Sci. Res. **2-B**: 19–30.

Fraenkel, G., and M. Blewett. 1942. Biotin, B_1, riboflavin, nicotinic acid, B_6, and pantothenic acid as growth factors for insects. Nature **150**: 177–9.

Fraenkel, G., and M. Blewett. 1944. The vitamin B complex requirement of several insects. Biochem. Jour. **37**: 686–95.

Fraenkel, G., and M. Blewett. 1945. Linoleic acid, tocopherol, and other fat soluble substances as nutritional factors for insects. Nature **155**: 392–3.

Fraenkel, G., and M. Blewett. 1946. The dietetics of the clothes moth *Tineola bisselliella* (Hum.). Jour. Expt. Biol. **22**: 156–72.

Fraenkel, G., and M. Blewett. 1947. The importance of folic acid and unidentified members of the vitamin B complex in the nutrition of certain insects. Biochem. Jour. **41**: 469–78.

Hegsted, D. Mark, R. C. Mills, C. A. Elvehjem, and E. B. Hart. 1941. Choline in the nutrition of chicks. Jour. Biol. Chem. **138**: 459–66.

Hobson, R. P. 1935. On a fat soluble growth factor required by blow-fly larvae. II. Identity of the growth factor with cholesterol. Biochem. Jour. **29**: 2023.

Loftin, U. C., K. B. McKinney, and W. K. Hanson. 1921. Report on investigations of the pink bollworm of cotton in Mexico. U. S. Dept. Agr. Bul. **918.**

Noland, J. L., J. H. Lilly, and C. A. Baumann. 1950. A laboratory method for rearing cockroaches, and its application to dietary studies on the German roach. Ann. Ent. Soc. Amer. **42**: 62–70.

Noland, J. L., and C. A. Baumann. 1951. Protein requirements of the cockroach, *Blatta germanica* (L.). Ann. Ent. Soc. Amer. **44**: 184.

Reiser, R., Betty Gibson, Mary Joyce Carr, and Beverly Jean Lamp. 1951. The synthesis and interconversions of polyunsaturated fatty acids by the laying hen. Jour. Nutr. **44**: 159–76.

Tatum, E. L. 1941. Vitamin B requirements of *Drosophila melanogaster*. Natl. Acad. Sci. Proc. **27**: 193–7.

Trager, W. 1947. A review with references. Cambridge Phil. Soc. Biol. Rev. **22**: 147–77.

Comparative Effectiveness of the Ethyl and Methyl Homologs of Nine Phosphorus Compounds Against Four Cotton Pests

E. E. IVY, C. F. RAINWATER, A. L. SCALES, and L. J. GORZYCKI, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

In the development of organic phosphorus insecticides, it is generally recognized that maximum activity of the pyrophosphates, the fluorophosphonates, and the aromatic substituted phosphates of the parathion type is usually associated with the presence of the $(C_2H_5O)_2P''$- or $[(CH^3)_2N]_2P''$-group. Replacement of these groups by the methyl or propyl group, or by hydrogen atoms, results in reduced activity (Schrader 1947; Thurston 1946; Brauer 1948). Metcalf (1948) called attention to the similarity in molecular dimensions of $(C_2H_5O)_2P''$- and $[(CH_3)_2N]_2P''$-groups, and suggested a critical-size relationship. In support of this concept, he pointed out the similarity in activity of the isopropyl and ethyl esters, which also have similar molecular dimensions. Ivy (1953) reported that in thiophosphoric acid esters of the Systox type, the isopropyl esters had about the same activity as the ethyl esters and were more active than the *n*-propyl esters, which would appear to substantiate Metcalf's concept of a critical-size relationship.

That there are marked differences in the effectiveness of certain alkyl substituents against different species of insects was shown by Metcalf & March (1949). They found that O,O-diisopropyl O-*p*-nitrophenyl thiophosphate was ineffective against bees and did not inhibit bee-brain cholinesterase, but that it was toxic to flies and inhibited fly-brain cholinesterase. They therefore concluded that specificity of insecticidal action was due to specific differences in enzyme properties. They also showed that the methyl homologs of para-oxon and parathion were slightly

[1] In cooperation with the Texas Agricultural Experiment Station.

more toxic to bees than the corresponding ethyl compounds, but that the ethyl compounds were slightly more toxic to flies.

Magee & Gaines (1950) tested the diethyl and dimethyl homologs of a mercaptoacetylurea thiophosphate and of a carbamylmethyl thiophosphate against several species of cotton insects. They found that the ethyl compounds were more toxic to the cotton aphid, *Aphis gossypii* Glov., the cotton fleahopper, *Psallus seriatus* (Reut.), a spider mite, *Septanychus* sp., and the differential grasshopper, *Melanoplus differentialis* (Thos.), but that the methyl compounds were more effective against the boll weevil, *Anthonomus grandis* Boh. Schrader (1951) reported that parathion and Potasan (O,O-diethyl 4-methylumbelliferone thiophosphate) were more toxic than their dimethyl homologs to white mice. Bottger & Yerington (1952) found that parathion was more effective than its dimethyl homolog against the citrus red mite, *Paratetranychus citri* (McG.), the large milkweed bug, *Oncopeltus fasciatus* (Dall.), and the celery leaf tier, *Phylctaenia rubigalis* (Guen.), but that the methyl compound was more effective against the pea aphid, *Macrosiphum pisi* (Kltb.).

From the foregoing it would appear that, although in general ethyl substituents confer greater activity on phosphorus insecticides than methyl substituents, there are exceptions to this rule, due perhaps to the specific differences between the enzymes of the various species, as suggested by Metcalf & March (1949). From fragmentary data available it appeared that the boll weevil was one of these exceptions.

Data on the relative toxicity of the methyl and ethyl homologs of nine phosphorus insecticides to four pests affecting cotton are presented in this paper.

MATERIALS.—The compounds included in the study are shown in table 1. In all cases they were used as received, having been previously purified, usually by distillation, and their identity characterized by elemental analysis.

The materials were formulated with an emulsifier, xylene, and water immediately before each day's test. All applications were made as sprays at the rate of 15 gallons per acre.

METHODS.—Tests were conducted against the boll weevil, the cotton aphid, the desert spider mite, *Tetranychus desertorum* Banks, and the cotton leafworm,

Table 1.—Dosage-mortality relationships of nine pairs of ethyl and methyl homologs of phosphorus compounds.

Compound	Pounds per Acre of Compound Required for Indicated Net Mortality							
	Boll Weevils		Cotton Aphids		Desert Spider Mites		Cotton Leafworms	
	LD-50	LD-90	LD-50	LD-90	LD-50	LD-90	LD-50	LD-90
O-*p*-Nitrophenyl thiophosphate								
0,0-Diethyl (parathion)[1]	0.150	0.413	0.022	0.143	0.081	0.640	0.002	0.523
0,0-Dimethyl (methyl parathion)[2]	.011	.176	.013	.102	.316	1.585	.051	.188
4-Methylumbelliferone thiophosphate[2]								
0,0-Diethyl (Potasan)	.165	.500	.054	.183	.032	.133	.109	.439
0,0-Dimethyl (Methyl Potasan)	.087	.347	.092	.733	.075	1.099	.069	.310
0-*p*-Nitrophenyl thionobenzene phosphonate[3]								
0-Ethyl (EPN)	.096	.221	.152	.440	.021	1.121	.001	.030
0-Methyl (MPN)	.082	.287	.336	.683	.071	1.359	.001	.056
0-2-Chloro-4-nitrophenyl thiophosphate[1]								
0,0-Diethyl (3677)	.195	1.645	.058	.293	.168	1.840	.087	1.323
0,0-Dimethyl (4142)	.181	.688	.035	.263	.546	6.942	.006	5.907
S-Carbamylmethyl dithiophosphate[1]								
0,0-Diethyl (3741)	.600	2.842	.003	.064	.308	.950	5.589	21.670
0,0-Dimethyl (3869)	.170	.672	.176	.747	.254	1.109	2.720	12.800
0-*o*-Nitrophenyl thionobenzene phosphonate[3]								
0-Ethyl (EON)	1.505	6.828	.274	.660	.031	.108	.048	.216
0-Methyl (MON)	.432	.705	.412	1.073	.104	.334	1.423	6.438
0-Ethylmercaptoethyl thiophosphate								
0,0-Diethyl (Systox)[4]	3.919	15.920	.003	.036	.013	.051	2.558	99.070
0,0-Dimethyl (Methyl Systox)[5]	3.093	11.480	.017	.074	.037	.138	4.533	23.320
S-Mercaptoacetylurea dithiophosphate[1]								
0,0-Diethyl (3885)	4.904	92.130	.009	.031	.022	.154	4.614	59.000
0,0-Dimethyl (3901)	1.527	10.730	.012	.054	.165	.464	.319	.823
Dithiopyrophosphate[6]								
Tetraethyl (3472)	3.069	7.970	.340	2.136	.220	2.906	.806	6.613
Tetramethyl (3650)	12.820	52.860	1.395	17.310	.605	2.219	1.323	9.327

[1] American Cyanamid Co.
[2] Geary Chemical Co.
[3] E. I. du Pont de Nemours Co.
[4] Pittsburgh Agricultural Chemical Co.
[5] Bayer, A. G.
[6] Monsanto Chemical Co.

Alabama argillacea (Hbn.). Boll weevils collected near Mante, Mexico, were used; the other species were reared in the laboratory. The cotton leafworm was tested in field cages in the manner described by Ivy & Scales (1950). Tests with the desert spider mite and the cotton aphid were conducted in the manner described by Gaines *et al.* (1950). Boll weevils were tested in laboratory cages, on potted cotton plants, but otherwise as described by Ivy & Scales (1950). The test period was 5 days for the boll weevil and the cotton leafworm and three days for the other species.

Untreated check plants were included in each test, and net mortalities were calculated by Abbott's formula. Dosage levels were selected, so that net mortalities ranging from less than 50 to more than 90 per cent were obtained for each compound. At least three dosages in this range were used for each species, and after the range was established by preliminary tests, replicate tests were conducted within the established range. From data thus obtained dosage-mortality lines were calculated according to the procedure described by Bliss (1938). For each of the dosage-mortality lines from 1,000 to 2,500 aphids or spider mites, from 150 to 400 boll weevils, and from 300 to 700 third-instar larvae of the cotton leafworm were used.

RESULTS AND DISCUSSION.—LD-50 and LD-90 values calculated for the 18 compounds are given in table 1.

Against the boll weevil the LD-50 was always lower for the methyl compound than for the corresponding ethyl compound, with one exception—tetramethyl dithiopyrophosphate. In one instance the difference between two compounds was extreme—methyl parathion was 13.6 times as effective as parathion. Some methyl compounds were 2 to 3 times as toxic as the ethyl compounds, and others, such as 0-methyl 0-*p*-nitrophenyl thionobenzene phosphonate, Systox, and 0,0-dimethyl 0-2-chloro-4-nitrophenyl thiophosphate showed little difference in toxicity. In case of the last two pairs of compounds, however, the slope of the line, another criterion for toxicity, is greater for the methyl compounds than for their ethyl homologs.

Less confidence can be placed in the LD-90 than the LD-50 value, because of statistical limitations, but it is of interest to note that the LD-90 of the methyl compounds were all lower than for the ethyl compounds, with the exception of tetramethyl dithiopyrophosphate and methyl parathion.

Against the cotton aphid the comparative toxicities were generally just the opposite of those found for the boll weevil. The ethyl compounds have lower LD-50's with only two exceptions—parathion and 0,0-diethyl 0-2-chloro-4-nitrophenyl thiophosphate. Although most of the ethyl compounds were 2 to 3 times as effective as the corresponding methyl compounds, Systox was nearly 6 times as effective and 0,0-diethyl S-carbamylmethyl dithiophosphate 58.7 times as effective as their dimethyl homologs.

Results with the desert spider mite were similar to those with the cotton aphid. The ethyl compounds were more toxic in eight pairs. There was only one exception: 0,0-dimethyl S-carbamylmethyl dithiophosphate was slightly more effective at the LD-50 level than its diethyl homolog. The two exceptions to the general order of toxicity found with the cotton aphid did not carry over to the spider mite, and the pair of compounds that differed most against the cotton aphid showed a reversed order of toxicity in tests against the spider mite.

In tests against the cotton leafworm the ethyl compounds were more effective for five of the pairs of compounds, whereas the methyl compounds were more effective for four of the pairs.

CONCLUSIONS.—We may conclude, therefore, that the findings have supported the hypotheses made at the beginning of the study—namely, that the boll weevil is an exception to the general order of toxicity. Of the ethyl and methyl homologs of nine phosphoric acid esters, the ethyl compound is usually more effective against the cotton aphid, the desert spider mite, or the cotton leafworm but not against the boll weevil. Exceptions were found with each species, however, and there appeared to be no consistent pattern to these exceptions, or to the variations in the relation between the dosages required for the two homologs against the different species.

Two important facts emerge from the study. In the first place, in the development of new phosphorus compounds for

the control of the boll weevil, compounds having methyl substituents should receive priority. However, in view of the exceptions, in the absence of actual tests we should be very careful in making too broad generalizations or assumptions concerning the specific performance of any new compound.

LITERATURE CITED

Bliss, C. I. 1938. The determination of the dosage-mortality curve from small numbers. Quart. Jour. Phar. and Pharmacol. 21(2): 192.

Bottger, G. T., and A. P. Yerington. 1952. Comparative insecticidal value of EPN, methyl ethyl parathion, methyl parathion, and parathion. JOUR. ECON. ENT. 45(1): 131.

Brauer, R. W. 1948. Inhibition of choline esterase activity of human blood plasma and erythrocyte stromata by alkylated phosphorus compounds. Jour. Pharmacol. and Expt. Ther. 92(2): 162–72.

Gaines, J. C., E. E. Ivy, H. A. Dean, and A. L. Scales. 1950. Toxicity of various sulphur and phosphorus compounds applied as sprays on spider mites and aphids. JOUR. ECON. ENT. 43(5): 614–9.

Ivy, E. E. 1953. Chemical characteristics of phosphorus compounds to kill aphids and spider mites by systemic action. Agr. Chem. 8(4): 47–50, 137, 139.

Ivy, E. E., and A. L. Scales. 1950. Dieldrin for cotton insect control. JOUR. ECON. ENT. 43(5): 590–2.

Magee, W. J., and J. C. Gaines. 1950. Toxicity of phosphorus compounds to various insects. JOUR. ECON. ENT. 43(3): 281–6.

Metcalf, Robert L. 1948. The mode of action of organic insecticides. Natl. Res. Council, Chem.-Biol. Coordination Center, Rev. 1, 84 pp.

Metcalf, Robert L., and Ralph B. March. 1949. Studies of the mode of action of parathion and its derivatives and their toxicity to insects. JOUR. ECON. ENT. 42(5): 721–8.

Schrader, Gerhard. 1947. The development of new insecticides. British Intelligence Objectives Subcommittee Final Rpt. 714 (rev.), Item No. 8, H. M. Stationery Office, London.

Schrader, Gerhard. 1951. Die Entwicklung neuer Insektizide auf Grundlage organischer Fluor- und Phosphor-Verbindungen. Monog. zu "Angew. Chem." u "Chem.-Ingen. Tech.," No. 62, 61 pp. Verlag Chemie, G.M.B.H., Weinheim.

Thurston, J. T. 1946. Organic chemical intermediates for insecticides, fungicides, and rodenticides. U. S. Off. Tech. Serv. PB Rpt. 60890, 44 pp. (Processed).

Field Tests with Sprays for the Control of Thrips and the Cotton Fleahopper

C. R. PARENCIA, JR., and C. B. COWAN, JR., *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1,2]

Early season damage by thrips, *Frankliniella* spp., and midseason damage by the cotton fleahopper, *Psallus seriatus* (Reut.), in central Texas during 1952 afforded an opportunity for tests to be conducted at Waco, Texas, with various insecticides applied as sprays for the control of these insects. The experiments against thrips were begun early in June and against the cotton fleahopper during late June and early July. Infestations of the bollworm, *Heliothis armigera* (Hbn.), were also studied after the use of insecticides against the cotton fleahopper.

EXPERIMENTAL PROCEDURE.—In small plot experiments, plots 16 or 20 rows wide and 0.2 acre in size were arranged in randomized blocks, with four replications of each treatment. Emulsion sprays were applied with a cart-type, four-row, hand-drawn machine constructed especially for spraying small plots, and its performance was similar to that of tractor-mounted spray machines used in the large-scale experiments. A small gasoline engine was used to drive the pump. The cart containing the spray equipment was mounted on two bicycle wheels and was drawn by one man at an approximate speed of 3 m.p.h. One nozzle per row was used, and the total volume of spray applied was 1.5 gallons per acre. The plots in large-scale experiments ranged in size from 2 to 10 acres. The emulsion sprays were applied with eight-row, low-pressure, low-volume spray machines, mounted on tractors. One nozzle per row was used and the total volume of spray applied was 2 gallons per acre, always at a pressure of 60 pounds per square

[1] In cooperation with the Texas Agricultural Experiment Station.

[2] This work was conducted under the general supervision of K. P. Ewing.

inch. The amount of emulsion concentrate ranged from 0.25 pint to 1 quart per acre, depending upon the desired dosage of technical toxicant.

EXPERIMENTS AGAINST THRIPS.—The thrips infesting the cotton were determined to be *Frankliniella exigua* (Hood) and *F. fusca* (Hinds). The initial applications were made when the cotton was in the four-leaf stage. Treatments and population counts are shown in table 1.

The populations were determined by collecting 10 plants at random from each plot, bringing them to the laboratory, striking the tops of the plants across the black rubberized surface of a table, and

Table 1.—Effectiveness of several organic insecticides against thrips on cotton.

Insecticide	Pounds of Toxicant per Acre[1]	Average Number of Thrips per Plant			
		Before Treatment	After Treatment		Seasonal Average
			1 Day	5 to 9 Days	
Small-Plot Experiments					
Experiment 1 (3 applications, June 4, 11, and 20)					
Toxaphene	0.75	2.7	0.3	2.2	1.6
Aldrin	.125	3.0	.3	1.9	1.3
Dieldrin	.0625	3.7	.2	1.5	1.1
Heptachlor	.25	3.5	.2	2.2	1.6
BHC+DDT	.15+.25	3.1	.3	3.1	2.2
Isodrin	.1	2.9	.5	3.1	2.2
Difference required for significance, 5% level	—	—	—	.8	.6
Untreated outside check	—	2.6	4.6	11.8	9.4
Experiment 2 (3 applications, June 3, 12, and 18)					
Toxaphene	0.75	3.4	0.4	1.9	1.2
Heptachlor	.0625	4.2	1.4	4.0	2.9
	.125	3.5	.6	2.7	1.8
	.25	3.2	.4	2.7	1.7
Endrin	.05	5.2	.8	3.0	2.1
	.1	3.2	.6	2.8	1.8
Difference required for significance, 5% level	—	—	.4	1.1	.7
Untreated outside check	—	4.9	4.3	5.1	4.8
Experiment 3 (3 applications, June 5, 12, and 19)					
Toxaphene	0.75	3.9	0.4	1.9	1.2
EPN	.125	3.9	.1	2.4	1.3
	.25	3.8	.1	1.8	.9
Heptachlor	.125	2.5	.2	2.6	1.4
Aldrin	.125	4.5	.5	2.9	1.7
Endrin	.1	4.6	.3	2.8	1.5
Difference required for significance, 5% level	—	—	.2	.7	.4
Untreated outside check	—	5.8	7.3	9.8	8.6
Large-Scale Experiments					
Experiment 4 (3 applications, June 5, 12, and 19)					
EPN	0.125	3.2	0.1	2.8	1.4
BHC	.15	3.1	.2	3.6	1.9
BHC+DDT	.075+.125	1.9	.4	2.8	1.6
Toxaphene	.75	1.1	.5	1.5	1.0
Untreated check	—	2.9	4.6	6.9	5.8
Experiment 5 (3 applications, June 5, 12, and 19)					
Isodrin	0.1	3.5	1.2	5.6	3.4
Endrin	.1	3.2	.7	6.0	3.3
EPN	.125	4.0	.3	4.7	2.5
Toxaphene	.75	2.0	.5	2.8	1.7
Untreated check	—	3.5	7.5	7.2	7.4
Experiment 6 (3 applications, June 5, 12, and 19)					
Heptachlor	0.125	7.1	0.2	4.1	2.2
Aldrin	.125	7.2	.7	1.9	1.3
Dieldrin	.1	8.0	.2	1.3	.8
Toxaphene	.75	6.3	.5	2.7	1.6
Untreated check	—	5.9	8.7	10.4	9.6

[1] Dosages for BHC refer to the gamma isomer.

counting the dislodged insects. These records were made 1 day and 5 to 9 days after each insecticide application.

In the small-plot experiments, untreated plots were not included within the randomized-block experimental design, but were located in the same fields adjacent to the treated plots.

In experiment 1 each insecticide gave almost complete initial kill of the thrips, as indicated by the records made 1 day after treatment. The records for 5 to 9 days after each application and the seasonal average of all the records made after treatment started show that toxaphene, aldrin, dieldrin, and heptachlor gave significantly better residual control of thrips than BHC plus DDT or isodrin.

In experiment 2, 1 day after treatment heptachlor at 0.0625 pound per acre was significantly less effective than other treatments. The records for 5 to 9 days after treatment and the seasonal averages show that the two highest dosages of heptachlor were significantly better than the lowest dosage, and that toxaphene was significantly better than the lowest dosage of endrin.

In experiment 3, 1 day after treatment EPN was significantly better than toxaphene, aldrin, and endrin. The records for 5 to 9 days after treatment show that toxaphene and EPN at 0.25 pound per acre were significantly better than heptachlor, aldrin, and endrin. The seasonal averages show that the 0.25 pound of EPN was significantly better than other insecticides except toxaphene, and that toxaphene was significantly better than aldrin.

In large-scale experiments toxaphene was used as the standard insecticide. It gave better residual control of thrips than EPN, BHC, and BHC plus DDT in experiment 4. In experiment 5 toxaphene gave better control than EPN, isodrin, or endrin. Dieldrin gave the best thrips control in experiment 6, and aldrin and toxaphene gave better control than heptachlor.

EXPERIMENTS AGAINST THE COTTON FLEAHOPPER.—During the last several years when the early-season insect control program was used in central Texas, the cotton fleahopper caused little or no damage later in the season. In 1952 the infestations were later than usual and became injurious by midseason.

Ewing and Parencia (1949) emphasized the importance of stopping early-season treatment at least 4 weeks before bollworms appear, to give beneficial insects ample time to build-up so that they might control or assist in controlling the bollworm. In 1950 they reported that in all early-treated fields beneficial insects became very abundant shortly after the cotton began to bloom and gave excellent control of bollworm eggs and young larvae.

Since the cotton fleahopper is easily killed with low dosages of most of the organic insecticides, several experiments were conducted to determine which insecticide when thus applied would be most effective during the mid-season when control of only this insect was needed. Such an insecticide should remain toxic for 10 to 14 days, so that one light application would give control without destroying beneficial insects.

The same small-plot experiments used for thrips control were utilized in the cotton fleahopper studies, but the large-scale experiments were different. In each experiment only one insecticide application for cotton fleahopper control was made. Treatments and residual toxicity, as indicated by records made 1, 6, 10, and in some experiments 13 days after treatment and the average infestation after treatment, are shown in table 2.

The applications made for thrips control apparently delayed cotton fleahopper build-up. At the time treatment was needed for their control the infestation in the treated plots of experiments 1 and 3 averaged 37 and 41 cotton fleahoppers per 100 terminals as compared with 63 and 67 in the respective outside untreated check plots.

None of the differences in control obtained with the various insecticides in the three small-plot experiments were significant. These experiments were unsatisfactory for evaluating the efficacy of different treatments against the cotton fleahopper, because the insect was easily killed with organic insecticides and an insecticide applied to each small plot apparently killed insects in adjoining plots. This is illustrated in experiment 2 (0.2-acre plots), in which no appreciable differences in control were obtained with three dosages of heptachlor. No significant difference was shown in residual control

Table 2.—Effectiveness of several organic insecticides against cotton fleahopper.

Insecticide	Pounds of Toxicant per Acre[1]	Number of Cotton Fleahoppers per 100 Terminals: Before Treatment	After Treatment: 1 Day	6 Days	10 Days	13 Days	Seasonal Average
Small-Plot Experiments[2]							
Experiment 1 (1 application, July 2)							
Toxaphene	0.75	34	3	10	14	—	9
Aldrin	.125	40	5	14	30	—	16
Dieldrin	.0625	40	1	15	14	—	10
Heptachlor	.25	39	3	11	15	—	10
BHC+DDT	.15+.25	32	6	9	19	—	11
Isodrin	.1	36	7	15	21	—	14
Untreated outside check	—	63	58	54	35	—	49
Experiment 2 (1 application, July 9)							
Toxaphene	0.75	33	8	10	6	—	8
Heptachlor	.0625	30	7	12	10	—	9
	.125	30	5	13	11	—	10
	.25	30	3	9	12	—	8
Endrin	.05	31	2	11	8	—	7
	.1	36	3	9	5	—	5
Untreated outside check	—	39	32	36	18	—	32
Experiment 3 (1 application, July 10)							
Toxaphene	0.75	35	4	17	—	8	10
EPN	.125	42	2	17	—	15	11
	.25	52	1	15	—	13	10
Heptachlor	.125	49	4	15	—	11	10
Aldrin	.125	38	4	15	—	9	9
Endrin	.1	30	2	12	—	6	6
Untreated outside check	—	67	55	48	—	27	43
Large-Scale Experiments							
Experiment 4 (1 application, June 24)							
Toxaphene	0.75	22	3	16	12	10	10
Dieldrin	.1	19	1	33	25	19	19
Aldrin	.125	28	4	38	39	29	28
Heptachlor	.125	21	5	49	36	36	31
Untreated check	—	18	13	39	37	34	31
Experiment 5 (1 application, July 1)							
Toxaphene	0.75	23	3	4	8	8	6
Dieldrin	.1	43	1	6	15	13	9
Aldrin	.125	36	2	16	31	18	16
Heptachlor	.125	62	2	22	32	28	21
Untreated check	—	32	17	39	31	39	32
Experiment 6 (1 application, July 2)							
Toxaphene	0.75	74	1	4	19	—	8
Dieldrin	.1	48	2	6	16	—	8
Aldrin	.125	48	3	10	22	—	12
Heptachlor	.125	41	3	14	35	—	14
Endrin	.1	38	.3	7	20	—	9
Isodrin	.1	42	4	8	31	—	14
Untreated check	—	27	25	22	35	—	27
Experiment 7 (2 replicates, 1 application, June 30)							
Toxaphene	0.75	34	1	7	8	8	6
BHC+DDT	.15+.25	30	.5	8	14	13	9
Endrin	.1	35	0	9	14	16	10
EPN	.125	40	.4	18	23	26	17
Untreated check	—	30	18	23	17	15	18

[1] Dosages for BHC refer to the gamma isomer.
[2] Untreated checks were not included in analysis of data.

obtained with these treatments and that obtained with toxaphene. However, in each of three large-scale experiments toxaphene gave much better control than the 0.125-pound heptachlor treatment. Results of the large-scale experiments gave a much better indication of the comparative effectiveness of the various insecticides in the control of the cotton fleahopper.

The same insecticides were used in large-scale experiments 4 and 5, but treat-

ment was made 1 week earlier in experiment 4. In that experiment, 1 day after treatment, dieldrin gave the best initial kill of the cotton fleahopper, but the other insecticides also gave good reductions. For the average after treatments toxaphene gave the best residual control, dieldrin the next best; heptachlor and aldrin gave poor control. The infestations in the latter treatments approximated that of the untreated check 6, 10, and 13 days after treatment.

Results in experiment 5 were similar to those obtained in experiment 4, except that residual control obtained with dieldrin compared more favorably with that obtained with toxaphene.

In experiment 6, 6 days after treatment, toxaphene, dieldrin, endrin, and isodrin gave better control than aldrin and heptachlor, but after 10 days toxaphene, dieldrin, and endrin gave better control than the other insecticides.

There were two replicates of each treatment in experiment 7. One day after treatment, each insecticide gave almost complete initial kill; 6 days after treatment, toxaphene, BHC plus DDT, and endrin each gave better cotton fleahopper control than EPN; and 10 and 13 days after treatment toxaphene gave the best control and BHC plus DDT and endrin each gave better control than EPN.

BOLLWORM INFESTATIONS.—Records of bollworm infestations made in the small-plot experiments during the 2-week period after treatment for cotton fleahopper control are shown in table 3.

In small-plot experiment 1 the bollworm infestation was light, and differences in degree of injury in plots treated with the various insecticides were not significant. The square and boll injury in these plots was slightly higher than in the untreated outside check plots.

In experiment 2 the bollworm square

Table 3.—Bollworm infestations after the use of insecticides for midseason control of cotton fleahoppers.

INSECTICIDE	POUNDS OF TOXICANT PER ACRE[1]	BOLLWORM INFESTATION			
		Number Per 100 Terminals (Av. of 3 records)		Per Cent Injured	
		Eggs	Larvae	Squares (Av. of 2 records)	Bolls (1 record)
Experiment 1 (1 application, July 2)					
Toxaphene	0.75	3	1	2	6
Aldrin	.125	3	2	2	5
Dieldrin	.0625	2	1	2	6
Heptachlor	.25	2	1	3	4
BHC+DDT	.15+.25	3	2	3	3
Isodrin	.1	4	1	1	3
Difference required for significance, 5% level	—	—	—	—	—
Untreated outside check	—	1	0.3	0.1	2
Experiment 2 (1 application, July 9)					
Toxaphene	0.75	21	4	9	10
Heptachlor	.0625	21	4	7	6
	.125	21	6	11	13
	.25	23	7	13	14
Endrin	.05	22	4	11	9
	.1	20	5	11	10
Difference required for significance, 5% level	—	—	—	3	—
Untreated outside check	—	15	4	8	8
Experiment 3 (1 application, July 10)					
Toxaphene	0.75	20	4	9	8
EPN	.125	16	7	11	14
	.25	17	7	16	16
Heptachlor	.125	17	4	8	10
Aldrin	.125	18	6	8	8
Endrin	.1	18	5	7	7
Difference required for significance, 5% level	—	—	—	4	5
Untreated outside check	—	18	3	7	7

[1] Dosages for BHC refer to the gamma isomer.

injury was significantly lower with the lowest dosage of heptachlor than with the other treatments except toxaphene and was significantly lower with toxaphene than with the highest dosage of heptachlor. The injury with toxaphene and with the lowest dosage of heptachlor was about equal to the injury in the untreated outside check. These results emphasize the importance of using the lowest dosage of an insecticide that will give satisfactory control of the cotton fleahopper during the midseason period. The lowest dosage of heptachlor could not be expected to give satisfactory cotton fleahopper control, but toxaphene at 0.75 pound per acre and endrin at 0.1 pound will both give satisfactory control. Differences in boll injury were not significant, but injury in the toxaphene and endrin treatments was only slightly higher than in the outside untreated check.

In experiment 3 the square injury records show that the bollworm infestation was significantly higher in plots treated with 0.25 pound of EPN than with the other insecticides. The boll injury records show that the bollworm infestation was significantly higher with both dosages of EPN than with toxaphene, aldrin, and endrin. The boll injury in the latter treatments was about the same as that in the outside check. These results indicate that EPN, even at 0.125 pound per acre, should not be used for cotton fleahopper control during the midseason period.

Records made in a large-scale experiment showed the same trend of increased bollworm infestations after the use of 0.125 pound of EPN per acre that was observed in the small-plot experiments. Two weeks after treatment for cotton fleahopper control the square injury was 13 per cent in the EPN-treated plots as compared with 6 per cent in the plots receiving toxaphene, endrin, and BHC plus DDT.

SUMMARY.—Insecticides applied as sprays were tested in several small-plot and large-scale field experiments conducted at Waco, Texas, during 1952 for the control of thrips, *Frankliniella* spp., early in the season and the cotton fleahopper, *Psallus seriatus* (Reut.), during the midseason period. Studies of infestations of the bollworm, *Heliothis armigera* (Hbn.), after the application of insecticides for cotton fleahopper control were also made.

The following insecticides and per-acre dosages gave the most effective thrips control: Dieldrin, 0.0625 pound and 0.1 pound; toxaphene, 0.75 pound; aldrin, 0.125 pound; heptachlor, 0.125 and 0.25 pound; and EPN, 0.25 pound. Residual control was not so good with BHC, 0.15 pound gamma plus DDT, 0.25 pound; BHC, 0.15 pound gamma; EPN, 0.125 pound; endrin, 0.1 pound; and isodrin, 0.1 pound.

Small-plot experiments were found to be unsatisfactory for evaluating the efficacy of different insecticides in the control of the cotton fleahopper. Records made in large-scale experiments 1 day after treatment showed good initial kill of the cotton fleahopper with toxaphene, 0.75 pound; dieldrin, 0.1 pound; aldrin, 0.125 pound; heptachlor, 0.125 pound; endrin, 0.1 pound; isodrin, 0.1 pound; BHC, 0.15 pound gamma plus DDT, 0.25 pound; and EPN, 0.125 pound. Records made 6, 10, and 13 days after treatment showed that the best residual control of the insect was obtained with toxaphene, dieldrin, endrin, and gamma BHC plus DDT; residual control obtained with aldrin, heptachlor, EPN, and isodrin was poor.

Bollworm injury after one application of EPN at the rate of 0.125 pound per acre for midseason cotton fleahopper control was significantly higher than after one application of toxaphene, 0.75 pound; aldrin, 0.125 pound; and endrin, 0.1 pound.

LITERATURE CITED

Ewing, K. P., and C. R. Parencia, Jr. 1949. Early-season application of insecticides for cotton-insect control. U. S. Bur. Ent. and Plant Quar. **E-792.**

Ewing, K. P., and C. R. Parencia, Jr. 1950. Early-season application of insecticides on a community-wide basis for cotton-insect control in 1950. U. S. Bur. Ent. and Plant Quar. **E-810.**

Effectiveness of Lindane Vaporizers[1]

R. A. Fulton, W. N. Sullivan, and G. F. Mangan, *Bureau of Entomology and Plant Quarantine, Agri. Res. Adm., U.S.D.A.*

Electrically heated devices for dispersing lindane vapors in enclosed spaces (Fulton *et al.* 1950, 1952) have recently come into widespread use. Such devices vaporize approximately 1 gram of lindane per day. During the past year experiments have been conducted to determine the operational characteristics of these lindane vaporizers, and the amount of vapor that may be present in a treated space.

A room with a capacity of approximately 11,000 cubic feet was selected for the tests. It had three large windows and two doors, which could be opened for ventilation. The vaporizer was mounted on the outside wall approximately 6 feet from the floor and 5 feet from the ceiling. The lindane was vaporized from a Pyrex cup approximately 3 inches in diameter and 2 inches high. The temperature of the air between the heating element and the cup containing the lindane was maintained at 118° C. The cup was weighed before and after each test to determine the amount that had been vaporized.

Because of excessive leakage of dichlorodifluoromethane from nearby refrigeration units, which caused high results in analyses by the total-chlorine method, the air samples were collected and analyzed by the method described by Hornstein & Sullivan (1951). The general arrangement of the sampling locations and the vaporizer unit is shown in figure 1. Locations 1 to 4 are 9, 5, 10, and 25 feet respectively, from the vaporizer unit-(*V*). With the exception of one test, all the samples and mortality data shown in the tables were obtained at location 1.

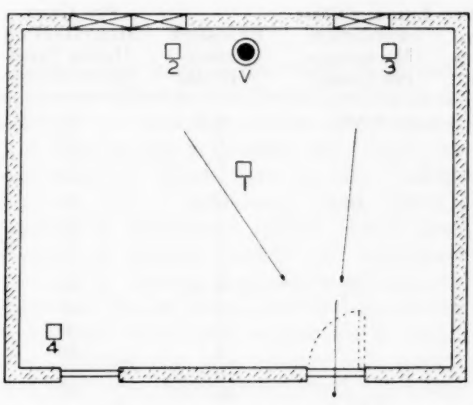


Fig. 1.—Diagram of room showing position of vaporizer unit and sampling locations.

In one test series air samples were taken at four locations in the room, with and without ventilation, to determine the variation in concentration caused by air exchange and convection currents. In a second test series the air was constantly circulated over the refrigerated coils of an air-conditioning unit to determine the effect on the lindane concentration. In another test, four vaporizers mounted on four walls were used to determine the amount of vapor present in the room and the effectiveness of this abnormal vapor concentration.

Screen cages containing nonresistant house flies were placed on clean surfaces, exposed for definite time intervals, and then removed and held until mortality counts were made at the end of 24 hours. Later, four species of roaches, the confused flour beetle, and carpet beetle larvae were exposed for evaluating the effectiveness of the lindane vapor. The room temperature was maintained at 85° F. during these tests with insects.

The results of the analyses to determine the distribution of the lindane vapor with and without ventilation are shown in table 1. When no ventilation was provided the concentration was uniform throughout the room, but when one window and one door were open samples taken at the same points showed a wide variation caused by eddy currents of air moving across the room, but with all the windows and one door open a uniform ventilation was obtained.

The results of the tests to determine the effect on the concentration of lindane in the air when it was constantly circulated over the refrigerated coils (48° F.) of an air-conditioning unit are shown in table 2 The tests were made during a period of high humidity, and approximately 2 gallons of water was removed during each

[1] Presented at the meeting of the American Association of Economic Entomologists at Philadelphia, Pa., December 15–18, 1952.

Table 1.—Lindane concentration, in micrograms per liter,[1] at four locations within a room with and without ventilation.

Test Conditions	Temperature (°F.)	Sampling Location 1	2	3	4
Room closed	89.5	0.11	0.18	0.17	0.12
One window and one door open	85	.12	—	.05	.30
Three windows and one door open	79	.042	.049	.044	.044

[1] To convert micrograms per liter to milligrams per 1,000 cubic feet multiply by 28.3

24-hour period. This water contained approximately 1 microgram of lindane per milliliter. The amount of lindane in the water removed by the air-conditioning unit had little effect on the concentration of lindane vapor in the air.

Four vaporizer units with enclosed thermostats set at the same temperature and each filled with a weighed amount of lindane from the same source were mounted in the same room, with the windows and doors closed, and operated for 3 days. At the end of this period losses in lindane ranged from 1 to 6 grams. The temperature had not changed except in the unit showing the minimum loss in weight, where it was 5 degrees lower.

The results of the chemical analyses and house fly mortality tests in the room with and without ventilation are shown in table 3. One test was made with the doors and windows closed, another with the doors and windows open, and a third with windows and doors closed but with the air

Table 2.—Effect on lindane concentration in a room with one vaporizer when the air was recirculated through an air-conditioning unit.

Temperature (° F.)	Time After Air-Conditioning Unit Was Started (Hours)	Relative Humidity (Per Cent)	Lindane (Microgram per Liter)
88	0	80	0.141
	3	65	0.295
	6	62	0.137
	7½	62	0.105
	24	50	0.079
85	72	50	0.093
	96	52	0.111
	120	55	0.111
80	168	45	0.120

within the room constantly circulated through the air-conditioning unit. The results corroborated previous findings (Fulton *et al.* 1952), and showed that a measurable amount of lindane vapor was always present even though there was a rapid exchange of air within the enclosed space. The air exchange during the test with the windows and doors open was approximately 3,000 cubic feet per minute.

To determine the effectiveness of the lindane vapor for periods of long exposure without ventilation, two tests were made against four species of roaches, carpet beetle larvae, and the confused flour beetle. For the first test only one vaporizer was used. For the second test four vaporizers were used to determine the effect of

Table 3.—Lindane concentration and mortality of house flies in tests with one vaporizer in a 11,000 cubic foot room.

Test No.	Test Conditions	Lindane Vaporized in 24 Hours (Grams)	Lindane Concentration (Microgram per Liter)	Exposure Period (Hours)	Per Cent Mortality of House Flies in 24 Hours
1	Windows and doors closed[1]	1.7	0.067	0.5	44
				1	47
				2	79
				3	97
2	Windows and doors open[1]	1.7	.016	0.5	11
				1	38
				2	55
				3	62
3	Windows and doors closed with air-conditioning unit operating continuously[2]	.91	.17	0.5	78
				1	100
				2	100
				3	100
				8	100
				24	99

[1] Average of results obtained on 2 days.
[2] Results obtained on 1 day.

Table 4.—Effectiveness of lindane-vaporizer units against several insects in a room without ventilation.

Lindane Vaporized in 24 Hours (Grams)	Lindane Concentration (Micrograms per Liter)	Exposure Period (Days)	Per Cent Mortality					
			American Cockroach	Oriental Cockroach	German Cockroach	Brown-Banded Roach	Confused Flour Beetle	Carpet Beetle Larvae
			One vaporizer					
0.91	0.17	1	6	0	0	90	0	0
		7	38	42	70	100	0	0
		11	63	96	91	100	10	0
			Four vaporizers					
4	.33	3	69	99	—	100	98	4

abnormally high vapor concentration. Table 4 shows the brown-banded roach to be the most susceptible of the roaches to the vapor of lindane and the American cockroach the least. The confused flour beetle appears to be susceptible when exposed to high concentration, but there was practically no effect on the carpet beetle larvae.

SUMMARY.—Tests to determine the operational characteristics and effectiveness of lindane vaporizers were conducted in a large room. These tests showed that the concentration of the vapor, based on determinations made at the same locations, ranged from 0.11 microgram per liter in a closed room to 0.044 microgram in a room with three windows and a door open. Air-conditioning units had little effect on the concentration of the vapor. House flies were controlled after 3 hours, even though the room was constantly ventilated. Four species of roaches were affected by the vapor present in nearly air-tight rooms after 11 days' exposure.

LITERATURE CITED

Fulton, R. A., R. P. Gelardo, and W. N. Sullivan. 1952. Relative efficiency of methods of applying lindane in enclosed spaces. JOUR. ECON. ENT. **45**(3): 540–1.

Fulton, R. A., R. H. Nelson, and F. F. Smith. 1950. The toxicity of lindane vapor to insects. JOUR. ECON. ENT. **43**(2): 223.

Hornstein, I., and W. N. Sullivan. 1953. The determination of lindane in air. Analyt. Chem. **25**(3): 496–8.

Effect of Different Treatment Schedules for Control of Cotton Insects[1]

R. L. HANNA and W. J. MISTRIC, JR.

There has been some work done each year since 1946 at the Texas Station in an attempt to evaluate various early season and late season schedules for cotton insect control. Work done in the College Station area by Gaines, *et al.* (1947), Gaines, & Wipprecht (1948) (1950) and Hanna & Gaines (1952) has indicated that early season application of insecticides on limited areas resulted in earlier fruiting of cotton but no increase in yield. Also, during the late season boll weevil and bollworm infestation period, the number of applications were reduced by confining the late season applications to a period which usually corresponds to the bollworm infestation period. This allowed the plants to set all the fruit that they were capable of maturing during that time. However, attempts to lengthen the 5-day treatment interval in order to reduce the number of applications were not successful.

The increase in mechanical harvesting and the uncertain availability of labor for hand harvesting have augmented the advantages of having all the bolls that the

[1] Technical Contribution No. 1733, Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture

Table 1.—The average thrips, fleahopper, boll weevil and bollworm infestation and yield of seed cotton on experiment 1 at College Station, Texas.

Treatments—Early Season Applications	Thrips on 20 Plants[1]	Fleahoppers on 100 Terminals[2]	Squares Punctured by Boll Weevils[3]	Per Cent Bolls Injured by Bollworms[4]	Pounds per Acre
None	43.5	11.9	20.1	3.3	975
1	47.7	7.3	15.0	3.2	956
2	29.3	8.8	14.2	3.0	1007
3	10.4	11.7	14.8	3.2	992

[1] Average of 72 counts on 6 different dates.
[2] Average of 36 counts on 3 different dates.
[3] Average of 60 counts on 5 different dates.
[4] Average of 48 counts on 4 different dates.

plants are capable of producing mature early and as near the same time as possible. Therefore additional research along these lines is both practical and desirable. The work done in 1952 is herein reported.

Experiment 1 was a randomized block test which was designed to compare the effectiveness of 1, 2 and 3 early season applications. The plats averaged approximately 1.5 acres in size and there were 4 plats in each block. The four replicates were in different fields. One plat in each block received 3 early season applications of insecticides, the first when the cotton was in the 4 to 8 leaf stage, the second 7 to 10 days later and the third 7 to 10 days after the second. A second plat in each block received only the last two applications and a third received only the last. The remaining plat in each replicate was not treated during this period. Toxaphene spray was applied at approximately 0.9 pound active ingredient per acre for the first two applications but was increased to 1.6 pounds per acre for the last application, in order to kill over-wintered boll weevils, *Anthonomus grandis* Boh. Late season applications for all plats became necessary to control boll weevils the first week in July and had to be continued at 5-day intervals until most of the bolls were mature in mid-August for boll weevil and bollworm, *Heliothis armigera* (Hbn.), control. Insect infestation, square, and boll counts were made at 7-day intervals throughout the season. Seasonal averages of insect infestation and yield are shown in table 1. Square and boll counts are shown in table 4.

Analysis of variance indicates that thrips control was better on the plats which received three early season treatments than on those which were given only the last two applications. Those which had two applications had superior thrips control to those which received only the last application. There were no significant differences between treatments in either fleahopper, *Psallus seriatus* (Reut.), boll weevil or bollworm control. The light fleahopper infestation occurred between the early season and late season treatment periods and all plats were treated alike during the boll weevil and bollworm infestations. Square counts show that all plats receiving early season treatment reached their fruiting peak about one week ahead of those which received no early season treatments. There were no significant differences in yield between treatments.

Experiment 2 was a small plat randomized block test designed to compare the same three early season schedules as experiment 1, to compare a 4-day interval with an 8-day interval schedule for late season control and to test all possible combinations of these early season and late season schedules. This resulted in the 12 different treatment-schedule combinations shown in table 2. Each plat was 0.1 acre in size and there were 3 replicates of each treatment. All plats were dusted with 2.5 per cent dieldrin-40 per cent sulphur until the bollworm infestation made it necessary to add 5 per cent DDT to the formulation. The first two early season applications were made at an average rate of 5 pounds per acre and the third was made at an average rate of 11 pounds per acre. Late season applications were made at an average rate of 13 pounds per acre. Plats treated at 8-day intervals received only five late season applications while those treated at 4-day intervals received 9.

The first early season application controlled the thrips populations during the period of greatest intensity and consequently only those plats receiving three

Table 2.—The average thrips, fleahopper, boll weevil and bollworm infestation on experiment 2 at College Station, Texas.

Applications	Thrips on 20 Plants[1]	Fleahoppers on 100 Terminals[2]	Squares Punctured by Boll Weevils[3]	Squares Injured by Bollworms[3]	Bolls Injured by Bollworms[4]
Early Season Only	95.3	9.7	25.1	16.8	16.1
Early Season Only	60.0	7.5	19.1	21.3	12.9
Early Season Only	10.3	11.2	18.4	16.0	13.0
Late Season Only (8-day interval)	71.3	11.5	11.0	6.3	5.6
Late Season Only (4-day interval)	82.7	6.2	8.8	4.4	3.4
Early+1 Late (8-day interval)	95.0	6.4	12.7	6.4	4.6
Early+1 Late (4-day interval)	122.3	8.5	7.1	3.7	3.1
Early+1 Late (8-day interval)	56.0	6.2	15.6	7.0	6.3
Early+1 Late (4-day interval)	90.6	7.8	7.9	2.4	3.3
Early+1 Late (8-day interval)	16.7	4.5	14.4	8.3	9.6
Early+1 Late (4-day interval)	9.7	7.5	8.3	3.4	3.1
No Treatment	87.0	13.0	21.7	20.4	14.3

[1] Average of 3 records from May 22 to June 4.
[2] Average of 4 records from June 18 to July 9.
[3] Average of 7 records from July 14 to August 14.
[4] Average of 7 records from July 19 to August 20.

early season applications had significantly fewer thrips than the untreated plats. The light fleahopper infestation occurred between the early season and late season application periods and was apparently unaffected by the treatments. Those plats which were dusted during the late season control period had significantly less boll weevil damage than those that were not. However, the difference between the 4-day and 8-day interval was not significant. This may have been because the boll weevil infestation was never severe.

Although the bollworm infestation was never extremely heavy there was an average of 14 per cent injured bolls for a period of 6 weeks in the untreated plats. The differences in treatment yields were apparently due to differences in degree of bollworm control. The plats which received late season treatment had significantly less bollworm injury and yielded twice as much seed cotton as those plats which had no late season applications. Also the 4-day treatment interval was significantly better in both bollworm control and yield than the 8-day treatment interval. Yields are shown in table 3. Early season treatments did not increase yields and the square and boll counts in table 4 show no earlier fruiting for the early treated plats. A similar small plat experiment in 1951 showed significantly earlier maturity in the plats receiving early season treatment, Hanna and Gaines (1952).

Table 3.—Average yield per acre on experiment 2 at College Station, Texas.

Treatments	No Late Season Applications	Late Season Applications (8-day Interval)	Late Season Applications (4-day Interval)	Average
Applications—				
No early season	712	1500	1588	1267
1 early season	671	1389	1689	1250
2 early season	745	1303	1733	1260
0 early season	723	1219	1596	1179
Average	710	1353	1652	1239

Experiment 3 was a test of randomized block design set up to compare the relative effectiveness of aldrin-DDT (1–2), dieldrin-DDT (1–2) and toxaphene-DDT (2–1) as sprays for late season control of cotton insects both at 4-day and at 8-day treatment intervals. Each plat was 0.1 acre in size. Applications of insecticides were made from July 2 to August 6. Plats which were treated at 4-day intervals received 9 applications of insecticides while those that were treated at 8-day intervals received only 5. Toxaphene-DDT (2–1) was applied at an average rate of 2.9 pounds of active ingredients per acre. Aldrin-DDT (1–2) and dieldrin-DDT (1–2) were applied at an average rate of 0.8 pound active ingredient per acre. Average insect infestations and yields are shown in table 5.

Toxaphene-DDT and dieldrin-DDT controlled boll weevils more effectively at the 4-day treatment interval than aldrin-DDT. Toxaphene-DDT and dieldrin-DDT also gave better control of boll weevils at 4-day intervals than at 8-day

Table 4.—Average numbers of bolls and squares on 20 feet of row, experiments 1 and 2 at College Station, Texas.

Week	Form	No Early Season Applications	1 Early Season Application	2 Early Season Applications	3 Early Season Applications
		Experiment 1[1]			
2nd June	Squares	37	44	39	28
	Bolls	0	0	0	0
3rd June	Squares	94	125	110	100
	Bolls	0	0	0	0
4th June	Squares	180	239	211	227
	Bolls	1	3	3	4
1st July	Squares	212	214	190	209
	Bolls	17	20	20	22
2nd July	Squares	156	117	127	139
	Bolls	84	112	93	95
3rd July	Squares	99	100	108	88
	Bolls	122	342	152	152
		Experiment 2[2]			
2nd June	Squares	92	98	104	102
	Bolls	0	0	0	0
3rd June	Squares	187	194	185	180
	Bolls	0	0	0	0
4th June	Squares	317	318	289	345
	Bolls	12	15	16	15
1st July	Squares	339	338	348	363
	Bolls	67	86	77	60
2nd July	Squares	229	221	215	252
	Bolls	161	192	179	177

[1] Each entry an average of 12 counts.
[2] Each entry an average of 9 counts.

intervals. The control with aldrin-DDT at 4-day intervals was not significantly better than that obtained with the 8-day treatment interval. There were no significant differences in boll weevil control between the three mixtures when applied at 8-day intervals. All insecticidal treatments protected the cotton from damage by the relatively small number of bollworms present. The field in which this test was located suffered an extreme loss of fruit because of drouth and many

Table 5.—The average boll weevil and bollworm infestation and yield of seed cotton on experiment 3 at College Station, Texas.

Treatment	Average Per Cent Squares[1] Punctured by Boll Weevils	Average Per Cent Bolls[2] Injured by Bollworms	Yield Per Plat	Yield Per Acre	Yield Gain Over Check
Toxaphene-DDT (4-day)	13	.2	25.3	506	136
Toxaphene-DDT (8-day)	24	1.1	18.7	374	4
Dieldrin-DDT (4-day)	15	1.0	27.1	542	172
Dieldrin-DDT (8-day)	22	3.4	23.6	472	102
Aldrin-DDT (4-day)	24	1.9	25.6	512	142
Aldrin-DDT (8-day)	27	2.2	25.4	508	338
Check	43	5.6	18.5	370	—

[1] Average of 10 records made from July 7 to August 9.
[2] Average of 8 records made from July 18 to August 14.

squares saved from insects were shed later or never matured. This was probably the reason that the superior boll weevil control obtained with the 4-day treatment interval did not result in increased yield.

SUMMARY.—Replicated tests designed to evaluate the effectiveness of 1, 2, and 3 early season insecticidal applications both on a small plat basis and on a larger plat basis showed no significant differences in yield between the three treatment schedules and the control. The large plat test indicated a slightly earlier fruiting for all plats receiving early treatment than for the control plats. Small plat tests showed that an 8-day treatment interval did not compare favorably with a 4-day treatment interval under conditions of damaging boll weevil or bollworm infestation.

LITERATURE CITED

Gaines, J. C., W. L. Owen and Read Wipprecht. 1947. Effect of Dusting Schedules on Yield of Cotton. JOUR. ECON. ENT. 40(1): 113.

Gaines, J. C., and Read Wipprecht. 1948. Effect of Dusting Schedules on the Yield of Cotton during 1947. JOUR. ECON. ENT. 41(3): 410–2.

Gaines, J. C. and Read Wipprecht. 1950. Evaluation of Dusting and Spraying Schedules for Cotton Insect Control. JOUR. ECON. ENT. 43(2): 288.

Hanna, R. L. and J. C. Gaines. 1952. Evaluation of Dusting Schedules for Control of Cotton Insects. JOUR. ECON. ENT. 45(3): 549.

Performance of Malathon for Control of the Pea Aphid[1]

L. P. Ditman,[2] Amihud Kramer[3] and A. O. Saulsbury, Jr.[4]

In small plot tests in 1951, malathon compared favorably with DDT, parathion, and the systemic poison octamethyl pyrophosphoramide in reducing aphid population on peas (Ditman & Burkhardt, 1952). Plots receiving malathon emulsion sprayed at the rate of 1.25 pints of 50 per cent emulsifiable concentrate in 30 gallons of water per acre consistently outyielded plots receiving other treatments. Because of these favorable results an expanded program for determining further the practicability and performance of malathon was carried out in the spring of 1952. A small plot experiment was conducted for the purpose of determining minimum effective dosage and residues. The effect of malathon on flavor and quality of treated peas was studied. Because of unfavorable conditions for development of an aphid population, the first objective could not be accomplished. Extensive observations were made on commercial applications of malathon by ground sprayer and by plane. Malathon and DDT emulsion sprays were compared in ground treatment and observations were made on varying dosages of aerial sprays.

Several of the organic phosphorus compounds are highly effective against the pea aphid. They are generally superior to DDT and the other chlorine containing insecticides. The systemic phosphorus compounds, of which octamethyl pyrophosphoramide has been most thoroughly investigated, are effective in soil, seed, or foliage applications (Bronson & Dudley 1951; Casida *et al.* 1952), but they are undesirable because they leave small but persistent residues that apparently carry over into the canned product; furthermore, Ditman & Burkhardt, 1952, observed a 25 per cent reduction of germination when applied as seed treatment. Parathion is highly effective for the pea aphid and has been successfully used commercially in Maryland for several years in both plane and ground applications. The highly volatile phosphorus materials such as tetraethyl pyrophosphate have such a brief period of effectiveness that their successful use is dependent on a high initial mortality. Malathon has certain advantages over the insecticides mentioned above; it appears to be equal or superior to any available insecticide in effectiveness against the pea aphid; it is less hazardous to the operator than the other organic phosphorus materials; and it leaves no residues on vines or fruit if a period of about two weeks is allowed between treatment and harvest. Because of the long period of protection against build-up, it may be applied at a relatively early stage of pea plant development.

Experimental Approach.—In the small plot tests, residues were determined on vines from plots receiving the heaviest application of malathon and on canned peas from all treatments. The dosage rates of malathon 50 per cent emulsifiable concentrate on these plots were varied from 0.5 to 2 pints per acre in increments of 0.5 pint. Time of treatment and number of applications were varied for the heaviest rate as will be noted in the results.

Commercial treatments with ground equipment at 1.5 pints of 50 per cent emulsion in 25 gallons of water per acre were made to compare malathon with DDT emulsion. Airplane spraying with dosages ranging from 1 to 2 pints of 50 per cent emulsion in 3 to 4 gallons of water per acre were compared with commercial DDT aerosol treatments. Conclusions of the effectiveness of commercial applications of malathon were based on reduction of initial infestation, on the comparative performance with DDT as indicated above, on the general level of aphid population or build-up after treatment, and on the general virulence of the aphid infestation in the area involved as shown by examination of untreated fields.

Results and Discussion.—*Ground sprays.*[5] Observations were made on five fields of peas treated with a single application of 50 per cent emulsifiable malathon applied at the rate of 1.5 pints in 25 gallons of water per acre and on two fields

[1] Scientific Paper No. A396; Contribution No. 2416; of the Maryland Experiment Station, Department of Entomology.
[2] Research Associate Professor, Department of Entomology, Maryland Experiment Station.
[3] Professor of Food Technology, Department of Horticulture, University of Maryland.
[4] President, Saulsbury Bros., Ridgely, Maryland.
[5] This work was done with the cooperation of Chas. T. Wrightson & Sons, Easton, Md.

treated with 30 per cent DDT emulsion applied at 1.33 pints in 25 gallons of water per acre. These sprays were applied with a high clearance corn sprayer, as described by Black 1951, fitted with a broadcast boom as described by Ditman and Burkhardt, 1952. A virulent aphid infestation was present in the area and weather was such as to produce an average crop. Treatments were made when populations were between 35 and 100 aphids per sweep. The effectiveness of treatments was based on observations made approximately a week before harvest. Nature of treatments and results are given in table 1. Initial kills were high and the period of protection so long that even when made early in the development of the pea plant a single application allowed the crop to mature before a rebuild-up of population took place. This canner sprayed half his acreage with DDT emulsion and half with emulsifiable malathon. There was no question in his mind as to the superiority of malathon as an aphicide for pea aphids.

Table 1.—Low volume ground sprays, time of treatment, and observations on results as indicated by average aphids per sweep of 10 sweeps per field; all peas Alaska type, malathon 50 per cent emulsifiable liquid at 1.5 pints per acre.

Farm & Insecticide Used	Aphids per Sweep Before Treatment	Date of Treatment	Aphids per Sweep	
			May 13	May 21–22
Swan Malathon	50	May 5		3.5
Foreman Malathon		14		0.4
Colber Malathon		14		0.0
Pugh Malathon "A"[1]	100	8	2.0	12.0
Pugh Malathon "C"[1]	100	8	0.0	4.0
Ewing Malathon		5		1.4
Lyon DDT		2		400.0
Pugh DDT	100	8	5.0	5.0
Bloomfield None			60.0	
Stevens None			300.0	

[1] Formulation not known.

Airplane Spraying.[6]—In plane treatments, 50 per cent emulsifiable malathon was applied in concentrated water emulsion, from 1 to 2 pints per acre in 3 and 4 gallons of water. The first series of tests was conducted on Alaska peas near Ridgely. This canner has been using liquefied gas-DDT aerosols for pea aphid control so that the two methods could be compared in his fields. Nature of treatments and results are given in table 2; it is apparent that all concentrations of malathon were highly effective. It is of particular interest that maximum reduction of aphids occurred on the tenth day after treatment. Though sweep counts were not recorded, this canner kept close watch on all fields and there was no further build-up of aphid population on any malathon-treated fields.

On Engermann field 2 there was a rapid build-up after May 21 and retreatment was necessary. On the rest of this canner's acreage, the control obtained with DDT aerosols was variable; on some fields a single treatment was adequate, on others, 2 or 3 treatments were necessary.

Further observations on the effectiveness of air treatments were carried on with the cooperation of a canner[7] whose acreage was planted in the vicinity of Trappe. Though observations were not as extensive as at Ridgely, the senior author visited some of the fields three times, once before and twice after treatment. Nature of treatments and aphid population records are given in table 3. From observations made by the authors, it appeared that airplane spraying with malathon under favorable conditions was highly effective against the pea aphid but that the effectiveness of such treatments was greatly reduced by wind at time of application, and to some extent by inaccessibility of fields to plane flight. Large acreages can be quickly sprayed by plane but unfavorable weather for relatively long periods frequently delays treatments beyond the critical period when insecticides should be applied or greatly reduces the degree of control if treatments are made. It appears from the results of observations on plane and ground spraying that canners with large acreages should not depend on the airplane alone but should have ground equipment available preferably a low volume sprayer, to use when prolonged periods of adverse flying weather occur.

RESIDUE AND FLAVOR TESTS.—Samples of vines with pods from plots receiving heaviest treatments and canned samples from all treatments were analyzed for

[6] In cooperation with the Aerial Spray Company of Maryland, Easton, Maryland.

[7] Trappe Frozen Food Corp., Trappe, Maryland.

Table 2.—Airplane malathon spray and DDT aerosol treatment at Ridgely, Maryland. Aphids per sweep in the first four fields based on the average of 4 samples of 5 sweeps; in the remainder of the fields on the average of a sample of 10 sweeps.

Farm & Insecticide	Amt. per A.	Water per A. Gals.	Date Applied	Aphids per Sweep				
						—May—		
			May	3	4	5	13	21
Weaver 1								
Malathon "C"	1.5 pt.	3	3	32.5	7.2	1.3	0.0	
Weaver 2								
Malathon "C"	2 pt.	3	3	37.5	5.2	1.2	0.0	
Bishop								
Malathon "A"	2 pt.	4	4	38.7		0.2	0.0	
Engermann 1								
Malathon "A"	1.5 pt.	4	3	23.7	1.2	0.0	0.4	0.4
Engermann 2								
DDT aerosol	.6 lb.		3	25.0	0.4	0.3	0.2	5.0
Engermann 3								
DDT aerosol	.6 lb.		7					0.6

malathon.[3] Quality and flavor tests were made on canned samples of all treatments after 3- and 6-months storage by the triangular test method and after the 3-month period by the multiple taste test method (Kramer 1952).

No evidence of malathon was found on any vines or canned samples. In the triangular taste test at the 3-month period no treated samples showed flavors significantly different from the check. In the 6-month triangular tests the 1 pint per acre malathon treatment was significantly different from the check but since no difference was found between the heavier dosage and the check it is logical to assume that the significance may have resulted from chance or some factor other than insecticidal treatment. In the 3-month multiple taste test no treatment samples were significantly different from the untreated check, all samples including the check being rated "above average" quality.

Table 3.—Observations on airplane spray treatments with 50 per cent malathon emulsifiable liquid for pea aphid control on Alaska peas in the vicinity of Trappe, Maryland. Aphid counts based on average of 10 sweeps per field.

Farm	Pints Insecticide per A.	Gallons Water per A.	Date	Aphids per Sweep		
				May		
				3	13	21–22
Chance	1.5	3	May 7			5.0
Hirst 1	1	3	4			
	1.5	3	7	35	0.0	2.0
Hirst 2	1	3	4			
	1.5	3	7	30	2.0	0.4
Stevens	1.5	3	14		300.0	1.0
Sheridan	1.5	3	16			275.0[1]
Brooks	1.5	3	14		25.0	0.6
Brigella	1.5	3	7		1.2	
Bloomfield			None		60.0	

[1] Treatment applied in moderate wind followed by 0.31 inch rain, field retreated.

Table 4.—Results of residue and flavor tests.

	Pints per Acre	Date Treated May	Triangular Test No. Correct Selection		Multiple Taste Test and Score[1]
			3 Months	6 Months	
Malathon	0.5	16	9	8	+0.1
Malathon	1	16	6	12	+1.1
Malathon	1.5	16	4	6	+1.1
Malathon	2	16	6	8	+1.7
DDT 30% Emul.	1.33	16	5	10	+1.6
Malathon	2	27	8	6	+1.8
Malathon	2	16, 27	7	8	+0.8
Untreated					−1.0
For significance at 5%			11	11	1.0

[1] A rating of −2 undesirable, 0 average, +2 excellent quality.

SUMMARY.—Commercial ground spraying with 1.5 pints of 50 per cent emulsifiable malathon in 25 gallons of water per acre applied with a boom sprayer designed for broadcast peas gave an excellent initial kill of aphids, and on such sprayed peas rebuilding of aphid population did not occur. When weather conditions were favorable, plane spraying with 1.5 and 2 pints of 50 per cent emulsifiable malathon in 3 to 5 gallons of water gave results comparable to ground spraying. During unfavorable weather, particularly when wind was blowing, efficiency of plane treatments was reduced.

No residue of malathon was chemically

[3] Vine samples were analyzed by Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine, U.S.D.A. Canned samples by Dr. P. R. Averell, Analytical Research Laboratory, American Cyanamid Company.

detected on pea vines or on canned peas when a period of slightly more than 2 weeks had been allowed between time of treatment and harvest. Quality and flavor of canned peas were not impaired by the heaviest applications of malathon in ground sprays.

LITERATURE CITED

Black, D. T. 1951. High clearance self-propelled corn sprayer, U.S.D.A., Bureau of Plant Industry, Soils and Agr. Eng. Div. of Agr. Engn., Information Series No. 103.

Bronson, T. E., and J. E. Dudley, Jr. 1951. Two systemic insecticides for control of pea aphid. JOUR. ECON. ENT. 44(5): 747–50.

Casida, J. E., R. K. Chapman, and T. C. Allen. 1952. Relation of absorption and metabolism of octamethyl pyrophosphoramide by pea plants to available phosphorus. JOUR. ECON. ENT. 45(4): 568–77.

Davich, T. B., and J. W. Apple. 1951. Pea aphid control with contact and systemic insecticidal sprays. JOUR. ECON. ENT. 44(4): 528–33.

Ditman, L. P., and Geo. Burkhardt. 1952. Further experiments on pea aphid control. JOUR. ECON. ENT. 45(5): 880–1.

Kramer, A. 1952. Quality control simplified for practical product improvement. Food Engineering 24(12): 100–8.

Sterilization of Screw-Worm Flies with X-Rays and Gamma-Rays[1]

R. C. BUSHLAND and D. E. HOPKINS, *U. S. Dept. Agr., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The main objective of the research herein reported was to develop procedures for sterilizing large numbers of screw-worm flies, *Callitroga hominivorax* (Coq.). Sterilized flies were needed for field experiments to test the feasibility of controlling isolated natural populations of screw-worms through release of much larger numbers of sterilized insects.

Preliminary tests (Bushland and Hopkins, 1951) had shown that screw-worms could be sterilized by x-rays administered to pupae during their last 2 days of development. Males were sterilized with a dose of 2,500 r (roentgens), but females were more resistant and their sterilization required 5,000 r. Laboratory studies had indicated that sterilized males competed about equally with normal males for mates. If a normal female mated first with a sterilized male, she did not mate subsequently with a normal male, and laid only infertile eggs. In laboratory cage tests with mixed populations of x-ray-sterilized and normal flies, the proportion of hatchable eggs was related to the relative numbers of sterile and normal males.

The x-ray procedure for sterilizing flies, although entirely feasible for laboratory studies and small-scale field releases, would be quite expensive for mass production of the numbers of sterilized flies that might be required for large-scale releases. Large amounts of sterilizing radiations can be more cheaply obtained by using gamma-rays from a radio-cobalt source.

This paper describes comparative tests at the Kerrville (Texas) laboratory of the Bureau of Entomology and Plant Quarantine on the effects of gamma-rays and x-rays on screw-worm flies. The investigations had three purposes: (1) To compare the effects of x-rays and gamma-rays, and determine their relative efficiency in sterilizing flies; (2) to find at what age pupae were most easily sterilized; and (3) to find at what age of pupal development the insects best tolerated the adverse effects of sterilizing radiations.

GENETIC EFFECTS OF X-RAYS AND GAMMA-RAYS.—Detailed investigations on the genetic effects of ionizing radia-

[1] Portion of a dissertation presented by the senior author as partial fulfillment of the requirements for the degree of Doctor of Philosophy in Entomology at Kansas State College.

This research was accomplished through the generous cooperation acknowledged herewith:

Alexander Hollaender, Biology Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., loaned the cobalt-60 source, and C. W. Sheppard of that organization instructed the authors in its use. Mary Esther Gaulden, of the Biology Division, reviewed the manuscript.

Col. Dwight M. Kuhns, M.C., U. S. Army, arranged for the x-ray treatments made by Col. John Isherwood, M.C., and the staff of the X-Ray Therapy Section, Brooke Army Hospital, Fort Sam Houston, Tex.

E. F. Knipling, Bureau of Entomology and Plant Quarantine, suggested the fly-sterilization project and advised and encouraged the authors.

tions began with the discovery by Muller (1927) that mutations could be induced in *Drosophila melanogaster* Meig. by x-ray treatments. Muller's discovery was enthusiastically accepted by geneticists, who found x-rays to be a useful tool for increasing the mutation rate not only in insects but in various organisms ranging from viruses to higher plants and laboratory mice.

There are numerous publications in the fields of genetics and cytology dealing with the effects of radiations. The various papers have been reviewed and interpreted in comprehensive publications by Muller (1940 and 1941), Lea (1947), and Catcheside (1948). Muller (1940) concluded that—

> A given number of ionizations produced in *Drosophila* spermatozoa by irradiation result in the same number of gross structural changes regardless of (a) wave-length, from 50 kV x-rays to gamma-rays; (b) continuous dose or fractionation over a 3-week period; (c) fertilization immediately or 1 month after treatment; (d) radiation intensity, from 0.05 to 250 r./min., (e) temperature, from 5 to 37° C. Hence in spermatozoa undergoing irradiation, "primary effects" of individual ionizations accumulate independently until fertilization, and their final total number determines the number of structural changes produced.

The literature on the effects of x-rays and gamma-rays on other organisms seems to be in general agreement with Muller's conclusions on *Drosophila*.

When x-rays or gamma-rays penetrate matter, they dissipate their energy by ejecting electrons from the atoms through which they pass. Even less energy is required to break the chemical bonds that join the atoms in molecules. It is believed that the effects of ionizing radiations on protoplasm are to induce physical and chemical changes in the molecules. These changes may so alter the complex organic molecules of genes and chromosomes as to cause aberrations in their structure and composition and thereby affect their function. If the changes are too extreme, the cell degenerates. A change in genetic constitution of a sperm may not prevent fertilization of an egg, but the zygote may be incapable of developing to maturity, and usually dies in the embryonic stage. Geneticists call such a phenomenon a dominant lethal effect. It is believed that the sterility of irradiated screwworm flies is an expression of this dominant lethal effect.

Although *Drosophila melanogaster* has been most extensively studied, pronounced chromosomal changes resulting from x-ray treatment of other insects have been noted by various authors. White (1935 and 1937), treating four species of grasshoppers with x-rays, noted chromosomal changes in the spermatogonia at the first meiotic division after irradiation. Carlson (1941) x-rayed another species of grasshopper and found that the treatment caused chromosomal changes and a delay in spermatogenesis.

Whiting (1938), working with *Bracon hebetor* Say (= *Habrobracon juglandis*), found that a dose of 7,500 r of x-rays almost totally sterilized the males, and that about half the eggs fertilized by spermatozoa treated with 2,500 r were incapable of normal development.

Reynolds (1941) found that oöcytes of the fungus gnat, *Bradysia ocellaris* (O.S.) (=*Sciara ocellaris* O. S.), varied in their susceptibility to x-irradiation, depending upon their stage of development, and that the metaphase of meiosis, which occurred during the second day of adult life, was the most sensitive stage. Crouse (1950), using *Bradysia coprophila* (Lint.) (=*Sciara coprophila* Lintner), reported that when adult flies were exposed to x-rays at their most susceptible age (46 to 72 hours), about the same number of chromosomal breaks were induced by 2,000 r in oöcytes as by 4,000 r in spermatozoa.

Koller & Ahmed (1942) made cytological studies on the salivary gland chromosomes of larvae obtained from mating males of *Drosophila pseudoobscura* Frolowa, treated with 4,500 r of x-rays, to untreated females. They noted structural changes in 40 per cent of the chromosomes. Their results also suggested that spermatozoa of *D. pseudoobscura* and *melanogaster* were equally affected by similar doses of x-rays.

Demerec & Kaufmann (1941) treated males of *D. melanogaster* with 3,000 r of x-rays, and then observed the fertility of eggs laid by normal females mated to the males at various intervals after their irradiation. Eggs obtained from matings made at intervals of 1, 6, 7, and 12 days after irradiation were of similar viability, but the percentage of dominant lethals dropped after 19 days. It was concluded that immature spermatozoa were more resistant than mature spermatozoa.

Luce *et al.* (1948) held eggs and larvae of *D. melanogaster* at 28° C. and x-rayed them at different ages, ranging from 5 to 86 hours after oviposition. The insects were then reared to the adult stage, and counts were made on the number of eye facets. If the treatments were applied during an effective period of 48 to 72 hours of egg-larval life, the number of eye facets was reduced. Near the time of the beginning of the x-ray-effective period, the frontal sacs of the larvae were separating into optic and antennal lobes. After separation the areas grew rapidly. The data suggested that the x-rays reduced eye facets only after the optic area was determined and during the period of rapid growth.

TEST INSECTS.—The insects used in this study were screw-worm flies from the Kerrville laboratory colony. The Kerrville strain started with a stock of flies reared in the Bureau's Texas field laboratories since 1936. There have been frequent infusions of wild genes through collection of egg masses from wounded animals exposed to natural infestation.

Eggs were obtained by confining gravid females in shell vials containing small pieces of fresh lean beef, and holding them for approximately 2 hours at a temperature of 90° to 100° F. The flies oviposited on or adjacent to the meat, depositing their eggs in masses averaging about 200 eggs. The eggs were transferred to moist filter paper and held in a petri dish at room temperature, where they hatched within 24 hours.

Larvae were reared on a nutritional medium, according to the procedure described by Melvin & Bushland (1941). The larvae completed their growth after feeding for 6 days, and crawled from the rearing medium into damp sand, where they pupated within 24 hours.

The newly formed pupae were sifted from the sand, washed and dried, and transferred to screen-wire containers, which were held at a temperature of 80° F. and relative humidity of 95 to 100 per cent. The adults emerged in about 7.5 days.

As the flies began to emerge, the containers of pupae were opened and placed in standard laboratory fly cages, where the insects were allowed to complete emergence. The adults were held at room temperature and a variable humidity, and were provided with food and water.

During the second to fourth day of adult life, the insects mated, and most of the females were ready to oviposit at the age of 6 days.

RADIATION EQUIPMENT.—*X-ray Equipment.*—Pupae were x-rayed by the X-Ray Therapy Section of Brooke Army Hospital, Fort Sam Houston, Tex. Lt. Col. W. E. Barry, M.C., has described the x-ray treatment as follows: "The equipment used was a deep therapy unit. The factors used were 200 kilovolts, 20 milliamperes, one-fourth copper inherent filtration, no added filter, half-value layer of 0.9 mm. copper, 20×20 cm. field, 50 cm. distance, delivering 112 r (roentgens) per minute in air. The total doses were given as a single exposure."

The insects were exposed in a shallow wooden tray 19 cm. square and 3 cm. deep. The 50-cm. distance was measured to the middle of the exposure tray. Therefore, the top layer of pupae received a slightly greater dose than those exposed at the bottom of the tray. The estimated average treatment was an air dose of 5,000 r. The total dose may have been somewhat greater, owing to back scatter and secondary irradiation.

Gamma-Ray Equipment.—Gamma-ray treatments were applied at Kerrville with a cobalt-60 source loaned by the Biology Division of the Oak Ridge National Laboratory. This assembly consists of 48 cobalt slugs arranged in a cylindrical brass capsule to form a lattice 2.25 inches in diameter and 8 inches long. This capsule is surrounded by 4 inches of lead shielding. At the top of the capsule is a port closed by a lead-filled steel plug, which is lifted by remote control with a rope and pulley. When the source is in use, the lead-filled plug is replaced by a threaded steel plug on which is screwed a cylindrical aluminum chamber, 2 by 8 inches. Material to be irradiated is placed in the chamber, which is then screwed onto the steel plug and lowered into the cobalt lattice.

The activity of the source when measured at Oak Ridge in February 1952 was approximately 11 curies. C. W. Sheppard, of the Biology Division, supplied a graph showing the intensity of the radiation and its variation within the radiation chamber. Using that information and a decay curve

for cobalt-60 (half-life 5.3 years) it was possible to treat insects with satisfactory accuracy. Pupae near the wall of the chamber received a greater dose than those in the center axis; there was also some variation along the axis. During the work at Kerrville pupae were treated with gamma-rays at a rate of 70 ± 7 r per minute. This 10 per cent variation in dosage occurred within each treatment group, depending upon the position of each pupa. Thus, when a culture is said to have been treated with 5,000 r, individual insects within that culture received doses varying from 4,500 to 5,500 r.

EFFECTS OF THE IRRADIATIONS ON FLY EMERGENCE AND LONGEVITY.—The first tests were to compare the effects of x-rays and gamma-rays on adult emergence and fly longevity. Since there was considerable knowledge from earlier work on the effects of a 5,000-r dose of x-rays applied to 6-day-old pupae, pupae of that age were given this dose for comparison.

For each of three experiments a large culture of 6-day-old pupae was divided into groups of approximately 1,000, and all insects were treated within a few hours of each other. Treatments were made at room temperature and humidity; then the insects were returned to a temperature of 80° F. and a relative humidity of 95 to 100 per cent to await emergence. When the flies began to emerge, each treated group of pupae was placed in a separate emergence cage at room temperature and humidity.

When emergence was completed, the puparia were examined individually to determine the percentage of fly emergence. The experiment was performed three times at 7-day intervals, comparing flies treated with x-rays and gamma-rays with control flies, which were handled similarly but not exposed to irradiation. The data are assembled in table 1.

Table 1 shows the same sex ratio among emerging flies for x-ray and gamma-ray treatments as for the untreated controls. Since the per cent emergence of treated flies did not differ significantly from that of the untreated flies, the radiations appeared to have no effect on pupal mortality.

With the cultures irradiated on March 10 and 17, observations were made on the length of life of the variously treated flies. When the newly emerged insects were less than 24 hours old, they were anesthetized with carbon dioxide, separated according to sex, and then transferred to standard laboratory breeding cages, 100 males and 100 females being placed in each cage. The culture of March 10 was used to stock duplicate cages for each treatment, whereas the effects of the treatments of March 17 were observed in triplicate cages. After 12 days, when approximately half of the insects had died, the test was terminated. The mortality records are assembled in table 2.

Table 1.—Percentage of flies emerging and percentage of males among those adults when 6-day-old pupae were treated with 5,000 r of x-rays or gamma-rays computed from groups containing from 574 to 1,158.

Treatment Date (1952)	Treated with X-Rays		Treated with Gamma-Rays		No Treatment	
	Emergence	Males	Emergence	Males	Emergence	Males
March 10	50	46	50	47	49	44
17	71	48	66	53	66	48
24	69	47	80	48	81	47
Average	63	47	65	49	65	46

Table 2.—Per cent mortality of flies, held in the laboratory for 12 days, that emerged from pupae treated when 6 days old with 5,000 r of x-rays or gamma-rays.

Treatment Date	Treated with X-Rays		Treated with Gamma-Rays		No Treatment	
	Males	Females	Males	Females	Males	Females
March 10	73	49	83	41	32	82
49	40	53	72	42	60
17	43	72	42	68	35	37
	47	48	39	47	35	35
	54	65	45	54	29	48
Average	53	55	52	56	35	52

The results indicated that gamma-rays were no more harmful than x-rays so far as adult longevity was concerned. There was no apparent difference in mortality of irradiated and untreated female flies, but fewer males died in the control group. That observation was in line with earlier observations on x-ray treatments.

Since those comparisons of x-rays and gamma-rays indicated no difference between the two kinds of irradiation, and they agreed with published reports on the similarity of irradiation effects on other organisms, no further work was done with x-rays. Efforts were then concentrated on the remaining objectives of the program.

EFFECTS OF GAMMA-IRRADIATION ON LONGEVITY, FERTILITY, AND FECUNDITY OF ADULTS.—Beginning on March 10, a series of seven cultures of screw-worm pupae were treated with 5,000 r of gamma-rays at weekly intervals. Newly emerged flies were anesthetized with carbon dioxide and separated according to sex. For each culture one laboratory breeding cage was stocked with 100 irradiated males and 100 normal females; a second cage was stocked with 100 normal males and 100 irradiated females; and a third cage was stocked with 100 normal males and 100 normal females. When the flies were 10 to 13 days old, the females were forced to oviposit by confining them in shell vials containing pieces of fresh lean beef. The egg masses were counted, placed on moist filter paper, and held in covered petri dishes for hatching observations. At the time of egging the flies, the numbers of surviving males and females were recorded. The data are assembled in table 3.

The cages holding sterilized males plus normal females and normal males plus irradiated females were placed side by side in the laboratory and were subjected to similar conditions. The fly room was heated so that the temperature did not go below 80° F., but on warm days temperatures as high as 95° were recorded. Because of the variation in temperature from week to week, and the fact that individual cultures of screw-worms vary in vigor, the data obtained on one culture cannot be compared directly with those on another. However, the data on flies from the same cultures are comparable.

Table 3.—Longevity, fecundity, and fertility of flies treated with 5,000 r of gamma-rays that were caged with normal flies of the opposite sex.

Treatment Date (1952)	Mating[1]		Number of Surviving—		Number of Egg Masses[2]	Per Cent of Eggs that Hatched
	Males	Females	Males	Females		
March 10	R	N	17	18	11	0
	N	R	68	28	0	—
	N	N	?	40	20	80
17	R	N	58	63	31	0
	N	R	65	32	1s	0
	N	N	71	52	45	100
24	R	N	65	90	70	0
	N	R	73	30	3s	0
	N	N	59	47	45	100
31	R	N	54	74	55	0
	N	R	75	50	1s	0
	N	N	67	78	54	100
April 7	R	N	34	40	28	0
	N	R	36	33	0	—
	N	N	34	44	31	100
14	R	N	50	58	31	0
	N	R	58	49	6s	0
	N	N	61	64	21	100
22	R	N	27	22	16	0
	N	R	40	40	3s	[3]
	N	N	37	45	38	100

[1] R = 100 flies from pupae irradiated on the sixth day; N = 100 flies from pupae not irradiated.
[2] "s" indicates that the egg masses consisted of less than half the usual 200 ± eggs.
[3] 2 larvae hatched out.

Of the sterilized males confined with normal females during the preoviposition period, 43.6 per cent survived. In the companion cages of normal males plus irradiated females, 59.3 per cent of the males survived. Table 3 shows that in all seven cultures more normal than sterilized males survived, but that the difference was much greater in some cultures than in others. The mean difference in survival between normal and sterilized males was 15.7 ± 7.0 per cent. When tested for significance, the t value was 2.43, whereas the value required for significance at the 5-per cent level was 2.447. However, there seems to be little doubt that sterilization reduced male longevity.

In the records on surviving females it will be noted that the data are more erratic than those for males. Of the normal females, 52.1 per cent were alive at time of oviposition, whereas 37.4 per cent of the irradiated females were still living. The mean difference of 14.7 ± 10.0 per cent was not significant.

The records on egg-mass production show that irradiation greatly reduced the fecundity of the flies. The irradiated females either laid no eggs or produced small egg masses containing less than half the usual number of eggs. Approximately one-tenth of the eggs in those undersized masses developed partly. The embryos grew until spined larvae were visible within the egg shell, but in all except one culture the larvae died within the shell. In that culture two larvae hatched successfully. For practical purposes the females could be considered completely sterilized.

Normal females caged with sterilized males produced as many eggs as normal females mated to normal males. None of the eggs laid by normal females mated to irradiated males hatched, although a few developed spined larvae which died within the shell.

The incomplete embryonic development noted above is in agreement with

the genetics literature on dominant lethal effects reviewed earlier.

EFFECT OF TREATING FLIES WITH 5,000 TO 20,000 r.—Although the data in table 3 strongly indicate that gamma-ray sterilization affected the longevity of flies, the failure to obtain statistically significant data suggested another experiment. A large culture of pupae was divided into five groups of 500 pupae each. One group was left untreated to serve as controls, and the other four groups were treated with doses of 5,000, 10,000, 15,000, and 20,000 r of gamma-rays when the pupae were 6 days old. The insects emerged normally after 7.5 days at 80° F. and there seemed to be no difference in emergence between the untreated insects and those variously irradiated. The newly emerged insects were anesthetized and separated according to sex. Duplicate cages were stocked with 100 males and 100 females from each of the five sublots. The mortality records were taken after 7 days and again after 13 days. The data are assembled in table 4.

Table 4.—Longevity of screw-worm flies irradiated with gamma-rays on 6-day-old pupae.

	PER CENT MORTALITY AFTER—			
	7 Days		13 Days	
r-DOSE	Males	Females	Males	Females
None	24	24	77	84
	24	14	75	58
5,000	40	50	68	79
	41	47	99	67
10,000	51	44	83	67
	36	40	78	72
15,000	41	41	62	70
	36	46	79	71
20,000	35	38	77	75
	41	43	84	69

Considering the 7-day mortality readings it will be noted that fewer insects died in the untreated group than in those groups treated with gamma-rays. There appeared to be no difference in mortality over the range of 5,000 to 20,000 r. After 13 days as many insects had died in the untreated group as in the irradiated groups.

It seems strange that if 5,000 r caused some mortality, quadrupling this dose did not cause a higher death rate. Perhaps those insects receiving the greater doses were more adversely affected but were less active and thus lived as many days.

STUDIES WITH PUPAE 3 TO 7 DAYS OLD.—All work so far discussed has dealt with flies irradiated as 6-day-old pupae. Earlier work with x-rays had indicated that irradiating pupae 2 days old or younger did not produce the desired effects, as any flies that survived the treatment were fertile. However, no data had been obtained on pupae of intermediate ages. Therefore, tests were made with pupae from 3 to 7 days old in an effort to find an age at which they could be sterilized with a minimum dose, and at the same time be least harmed in so far as the treatment affected adult longevity.

The doses selected for study were 2,500, 3,000, 3,500, and 4,000 r. Since so many insects were involved, each dose was tested against a separate culture of flies. To produce a test culture approximately 20,000 eggs were obtained from the laboratory fly colony. The larvae were reared on the standard nutritional medium. When the greatest portion of the larvae were transforming into pupae, those pupating within a 12-hour period were selected for the tests. This group was divided into six sublots of 1,000 pupae each.

The insects were held at a temperature of 80±2° F. and a relative humidity of approximately 95 per cent. One group was left untreated to serve as controls, and the others were treated with gamma-rays when 3, 4, 5, 6, or 7 days old. The age of the insects at the time of irradiation was within 6 hours of the full number of days indicated. When the flies emerged, they were separated according to sex and held in duplicate cages, each containing 100 males and 100 females. Irradiated males were confined with normal females and normal males with irradiated females. To establish the fertility of the normal insects, two control cages were also set up with 100 normal males plus 100 normal females. The flies were observed daily, and in 10 to 13 days, when approximately one-half of the insects were dead, the test was terminated by counting the survivors and egging the females.

In table 5 are assembled the data on fly emergence and adult longevity. A dose of 3,000 r apparently had no effect on the mortality of the pupae regardless of their age. With a dose of 3,500 r, fewest

flies emerged when the treatment was applied to 3-day-old pupae, and the mortality decreased with increasing age at time of treatment. The effects of the 4,000-r dose were more obvious. The general trend of the data indicated that pupae 5 days or more old emerged normally, whereas those less than 5 days old suffered some mortality attributable to irradiation.

Table 5.—Effect of different doses of gamma radiation on fly emergence and adult longevity when pupae were treated at different ages.

r-Dose	Age of Pupae When Treated (Days)	Per Cent Mortality of Pupae	Per Cent Mortality of Adults in Duplicate Cages	
			Males	Females
2,500	3	—	48, 53	72, 81
	4	—	32, 58	33, 50
	5	—	39, 45	52, 55
	6	—	27, 40	33, 38
	7	—	33, 33	38, 42
	Control	—	22, 30	83, 83
3,000	3	17	69, 72	83, 90
	4	18	46, 66	80, 84
	5	18	35, 46	88, 94
	6	16	60, 66	66, 85
	7	21	53, 65	68, 74
	Control	15	73, 74	68, 82
3,500	3	29	62, 74	88, 88
	4	27	50, 53	56, 63
	5	22	39, 53	40, 59
	6	21	43, 51	44, 60
	7	18	50, 64	52, 57
	Control	—	29, 35	15, 20
4,000	3	50	96, 98	94, 95
	4	30	81, 85	91, 91
	5	15	84, 92	67, 69
	6	19	68, 70	54, 58
	7	18	55, 68	47, 68
	Control	17	47, 55	20, 37

The data on adult longevity suggested that doses of 2,500 and 3,000 r were tolerated when the pupae were treated at any time from the third to the seventh day. The doses of 3,500 and 4,000 r appeared to be especially harmful when applied to 3-day-old pupae. As usual the data were somewhat erratic. In many cases there was more difference within duplicates than between treatments, but generally the irradiation given older pupae had less effect on adult longevity. The insects tolerated the higher doses best when treated on the sixth or seventh day of the pupal period.

The records relating to the fecundity and fertility of the flies treated as pupae at various ages are assembled in table 6.

The dose of 2,500 r destroyed the reproductive capacity of males almost completely. The insects were not totally sterilized, because a small proportion of the eggs from normal females mated to the treated males developed spined larvae. However, most of these larvae died without hatching. There was no hatch in 50 egg masses laid by normal females mated to males treated with 2,500 r in the fifth day of pupal life. A very small percentage of the eggs laid by flies mated to males treated on the third, fourth, sixth, and seventh days hatched.

The dose of 2,500 r applied to 3-day-old pupae caused the females to lay fewer and

Table 6.—Effect of different doses of gamma radiation on fecundity and fertility of flies when pupae were treated at different ages.

r-Dose	Age of Pupae When Treated (Days)	Mating		Number of Females Surviving to Oviposit	Number of Egg Masses[1]	Per Cent of Eggs that Hatched
		Males	Females			
2,500	3	R	N	94	65	1
		N	R	47	15s	50
	4	R	N	98	55	0.5
		N	R	117	50	75
	5	R	N	51	50	0
		N	R	93	50	95
	6	R	N	25	25	4
		N	R	129	50	100
	7	R	N	50	35	1
		N	R	120	50	100
	Control	N	N	34	27	100
3,000	3	R	N	90	61	0.1
		N	R	17	4s	5
	4	R	N	79	55	0.1—
		N	R	36	14s	2
	5	R	N	79	48	0.1—
		N	R	18	6s	50
	6	R	N	60	55	5
		N	R	22	21s	50
	7	R	N	60	35	1
		N	R	58	24	42
	Control	N	N	50	33	85
3,500	3	R	N	152	105	0.01—
		N	R	24	0	—
	4	R	N	149	85	0.01—
		N	R	81	14vs	0.8
	5	R	N	132	80	0.01—
		N	R	101	11vs	7
	6	R	N	160	90	0.1—
		N	R	96	24s	40
	7	R	N	72	42	0.4
		N	R	109	24	50
	Control	N	N	165	110	100
4,000	3	R	N	79	40	0
		N	R	11	0	—
	4	R	N	78	49	0.1
		N	R	56	50 eggs	0
	5	R	N	58	29	0
		N	R	64	150 eggs	8
	6	R	N	83	56	0.8
		N	R	88	12vs	14
	7	R	N	68	43	0.8
		N	R	85	13vs	50
	Control	N	N	143	46	96

[1] "s" indicates the egg masses were less than half normal size; "vs" that they contained less than one-fourth the normal 200± eggs.

smaller egg masses, which were only 50 per cent fertile. That dose did not appear to affect females when given to pupae in later days of development.

Treatment with 3,000, 3,500, and 4,000 r affected the fertility of both males and females at all the ages treated. Males in the fourth and fifth day of the pupal stage were most susceptible to the gamma-rays. In all cases the lowest percentage of hatch occurred when the male parent was treated on those days. Irradiation on the third day had the greatest effect on fertility and fecundity of the females, but as few of the irradiated insects survived to oviposit, not many egg masses were produced. Females treated with a dose of 4,000 r on the fourth and fifth days did not produce sufficient eggs to deposit normal masses. Instead, the eggs were scattered as though each fly had laid only a few. The females irradiated on the sixth and seventh days laid their eggs in definite masses of 25 to 50 eggs.

The results from this series of treatments suggested (1) that there was no gamma dose below 5,000 r that was adequate to produce properly sterilized flies for release in field experiments, and (2) that pupae should be sterilized when 5 or 6 days old.

EXPERIMENTS WITH MIXED POPULATIONS OF STERILIZED AND NORMAL FLIES.—Before the cobalt-60 source was borrowed from the Oak Ridge National Laboratory, one test was made in cooperation with the Biology Division to ascertain whether gamma-sterilized males could compete for mates with normal males.

Screw-worm pupae were taken to Oak Ridge, where C. W. Sheppard, of the Biology Division, treated them with gamma-rays. As this was the first gamma treatment, a dose of 10,000 r was used in order to be fairly sure of sterilizing the flies. The insects were brought back to Kerrville, where they emerged in the laboratory. Eight fly cages were stocked with normal newly emerged insects, each cage with 10 males and 10 females, plus additional numbers of sterilized flies. When the insects were 8 days old, the females were forced to oviposit by the usual procedure. The results of the experiment are summarized in table 7.

Normal females mated to the irradiated males laid eggs that failed to hatch, but flies from the stock cage containing normal males and females produced eggs that hatched 100 per cent.

Table 7.—Observations on egg masses laid by normal females caged with sterile and normal males.

CAGE POPULATION 10 N MALES+10 N FEMALES+STERILIZED FLIES AS INDICATED	NUMBER OF EGG MASSES		AVERAGE PER CENT FERTILITY
	Laid	Hatched	
100 Males	7	3	36
	7	2	
100 Males+100 females	8	1	14
	6	1	
50 Males	9	4	33
	9	2	
50 Males+50 females	7	4	36
	7	1	

In the mixed-population cages the expected egg fertility was about 10 per cent where the sterilized males outnumbered normal males by 10 to 1 and approximately 20 per cent where the ratio was 5 to 1. The actual fertility greatly exceeded that expected on a hypothesis of equal mating activity of sterile and normal males. However, considering the small numbers of eggs on which the percentages were based and the high dose of gamma irradiation, the results were encouraging.

After the gamma source was established at Kerrville, one test was made with flies sterilized with a 5,000 r dose. Three cages were stocked with newly emerged flies. Each cage contained 100 sterilized males and 100 sterilized females with 20 normal males and 20 normal females. When insects were 10 days old, the females were forced to oviposit. The normal females from the first cage produced five egg masses, those from the second ten, and those from the third nine. One egg mass in each group hatched. Thus, of a total of 24 egg masses, only three, or one-eighth, were fertile. Since one-sixth of the male population consisted of fertile insects, it is concluded that, under cage conditions, males sterilized with 5,000 r of gamma-rays competed equally with the untreated males.

SUMMARY.—Experiments were made at Kerrville, Tex., to determine the effects on adult screw-worm flies, *Callitroga hominivorax* (Coq.), of treating pupae from the laboratory colony with gamma-

rays and x-rays. The test insects were irradiated with gamma-rays using a cobalt-60 source supplied by the Oak Ridge National Laboratory. Doses were applied with an accuracy of ±10 per cent. X-ray treatments were applied at Brooke Army Hospital, Fort Sam Houston, Tex., using a deep-therapy machine. Screw-worms were reared on the standard nutritional medium and were irradiated in the pupal stage. It was found that flies reared from 6-day-old pupae treated with 5,000 *r* were sterile.

Comparisons of three cultures of 6-day-old pupae treated with 5,000 r of x-rays or gamma-rays showed that both radiations produced similar effects. Neither treatment appeared to cause pupal mortality, but adult males from irradiated pupae did not live as long as normal males.

Using seven cultures of screw-worm flies, comparisons were made of normal insects with flies from pupae treated with 5,000 r on the sixth day. After 10 to 13 days 56.4 per cent of the normal males were dead. The mean difference, 15.7±7.0 per cent, approached significance at the 5-per cent level. Sterilization apparently reduced the longevity of the males. During the same period 62.6 per cent of the treated females but only 47.9 per cent of the untreated females died. There was even greater difference between cultures than in the case of the males, and the mean difference, 14.7±10.0 per cent, was not significant. Most of the female flies irradiated as 6-day-old pupae with 5,000 r of gamma-rays did not oviposit, and the few that did deposit eggs laid masses less than half as large as those produced by normal flies.

With doses of 2,500, 3,000, 3,500, and 4,000 r, pupae were treated after 3, 4, 5, 6, and 7 days±6 hours of development. The highest dose reduced fly emergence of 3- and 4-day-old pupae, but those 5 days or more old emerged as well as the untreated controls. Adult flies, both males and females, from pupae treated on the third and fourth days did not live as long as those treated on the sixth and seventh days.

Observations on the hatching of eggs obtained from normal females mated to irradiated males showed that male pupae treated on the sixth and seventh day were not as easily sterilized as were younger pupae. Females showed a similar response in so far as fertility was concerned.

It was indicated that no dose of less than 5,000 r could be depended upon to produce total sterility, and that it was best to sterilize pupae after they had completed 5 days of development.

When normal and sterilized screw-worm flies were caged together, the gamma-irradiated males competed for mates about equally with the normal males.

LITERATURE CITED

Bushland, R. C., and D. E. Hopkins. 1951. Experiments with screw-worm flies sterilized by x-rays. JOUR. ECON. ENT. **44:** 725–31.

Carlson, J. Gordon. 1941. Effects of X-radiation on grasshopper chromosomes. Cold Spring Harbor Symposia Quant. Biol. **9:** 104–11.

Catcheside, D. G. 1948. Genetic effects of radiations. Adv. in Genet. **2:** 271–358.

Crouse, Helen V. 1950. The differential response of male and female germ cells of *Sciara coprophila* (Diptera) to irradiation. Amer. Nat. **84:** 195–202.

Demerec, M., and B. P. Kaufmann. 1941. Time required for *Drosophila* males to exhaust the supply of mature sperm. Amer. Nat. **75:** 366–79.

Koller, P. C., and I. A. R. S. Ahmed. 1942. X-ray induced structural changes in chromosomes of *Drosophila pseudo-obscura*. Jour. Genet. **44:** 53–71.

Lea, D. E. 1947. Actions of radiations on living cells. 402 pp. New York, Macmillan.

Luce, W. M., H. B. Chase, and Henry Quastler. 1948. Effects of graded dosage of x-rays on the production of eye facets in the bar-eyed race of *Drosophila melanogaster*. Genetics **33:** 115.

Melvin, Roy, and Raymond C. Bushland. 1941. The nutritional requirements of screw-worm larvae JOUR. ECON. ENT. **33:** 850–2.

Muller, H. J. 1927. Artificial transmutation of the gene. Science **66:** 84–7.

Muller, H. J. 1940. An analysis of the process of structural change in the chromosomes of *Drosophila* Jour. Genet. **40:** 1–66.

Muller, H. J. 1941. Résumé and perspectives of the symposium on genes and chromosomes. Cold Spring Harbor Symposia Quant. Biol. **9:** 290–308.

Reynolds, J. Paul. 1941. X-ray induced chromosome rearrangements in the females of *Sciara*. Natl. Acad. Sci. Proc. **27:** 204–8.

White, M. J. D. 1935. Effects of x-rays on mitosis in the spermatogonial divisions of *Locusta migratoria*. L. Roy. Soc. London Proc., Ser. B. **119:** 61–84.

White, M. J. D. 1937. Effects of x-rays on first meiotic division in three species of Orthoptera. Roy. Soc. London Proc., Ser. B. **124:** 183–96.

Whiting, P. W. 1938. Decrease in biparental males by x-raying sperm in *Habrobracon*. Pa. Acad. Sci. Proc. **12:** 74–6.

Some Effects of Storage at Different Temperatures on the Lipids of the American Roach and on the Resistance of This Insect to Heat[1]

SAM C. MUNSON, *Department of Biology, The George Washington University, Washington, D. C.*

For a long time evidence has existed that the chemical structure of the lipids of an organism, either plant or animal, is influenced by the temperature at which their biosynthesis occurs; the generalization is that lipids which are produced or deposited at higher temperatures are more saturated than those at lower temperatures, all other conditions being equal. Also, organisms of warmer climates are commonly regarded as being more able to withstand high temperatures than are those of cooler zones. A type of heat coagulation (not to be confused with protein coagulation) apparently may be associated with some change in the fatty materials of cells exposed to unfavorably high temperatures (Heilbrunn 1924). These observations are essentially the basis for the 'lipoid liberation' theory of thermal injury at high temperatures (Bělchrádek 1931; Fraenkel & Hopf 1940, and Heilbrunn 1947).

This investigation was undertaken to determine the alterations which might occur in the saturation of the lipids of the American roach, *Periplaneta americana* L., held at different temperatures by determining the iodine numbers (the number of grams of iodine taken up by 100 grams of lipid) of extracted lipids; and to determine whether or not roaches with different iodine numbers would vary in their resistance to death induced by abnormally high temperatures .

In this paper lipid is used in its broader meaning to include not only true fats and waxes, but, also, chemically related substances, the phospholipids, and other substances related by their physical properties such as common solubility, and their biological relationship.

As the role of the fat body and the physiological functions of the lipids in insects are discussed in textbooks of comparative animal and insect physiology, and as a recent survey of the literature on insect lipids by Scoggin & Tauber (1950) covers the general aspects of the subject up to 1950, only a brief review of the factors which may cause variation in the lipids of insects need be considered here. These factors will be briefly compared with certain aspects of the general literature of lipids in other animals.

Timon-David (1930) determined iodine numbers for a large number of insects representing all major orders and found them to range from 1.5 for an aphid, *Pemphigus* to 164.5 for a moth, *Saturnia pyri* Sch. Orthoptera varied from 68.8 for the oriental roach, *Periplaneta* (*Blatta*) *orientalis* L., to 122.6 for a locustid grasshopper, *Oxya japonica* Will. The quantities of fat expressed as percentages of wet weight varied from 2.4 to 7.0 for seven Orthopterans. Iodine values for the German roach, *Blattella germanica* L., under experimental conditions were found to range from 51 to 64 by Melampy & Maynard (1937); and the lipid content expressed as percentage of wet weight was 5.72 for nymphs, 4.78 for female adults with egg capsules, and 1.70 for male adults. For the same species McCay (1938) found fat to be 15.6 to 17.1 per cent of dry weight (ca. 5.24–6.1 per cent of wet weight) with a water content of 64.3–66.3 per cent of body weight. Iodine numbers ranged from 55 to 57. According to the unpublished work of Schweet quoted by Scoggin & Tauber (1950) the American female adult roach has a lipid content of 28.63 per cent of dry weight (ca. 9.54 of wet weight) and the males 25.55 (ca. 7.12). All the above figures exceed the 4.3 per cent of wet weight reported by Timon-David for the lipid content of the oriental roach.

Stadium, caste, sex, and phase may have an influence on the lipids of an insect. Hibernation due to the intervention of diapause generally does not have a pronounced effect. Starvation, migration, systematic position, diet and temperature of the ambient medium may all play a role in determining the kind and quantity of lipids to be found in an insect. The last two factors are of great importance. Per-

[1] This paper is an abridgement of the first half of a thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at the University of Maryland.

haps as a generalization one may say that the lipids of an organism are determined by the interaction of (1) the genetic characteristics of the species, (2) the nature of the ingested lipids, and (3) temperature.

It is essential that certain aspects of diet as related to the present subject be taken into account. The nutritional availability of ingested fats must be considered. The melting point of these fats must be such that they are liquid or nearly so at the temperature of the animals body. Food fats of different origin seem to be about equally available if they have sufficiently low melting points; but the melting point may not be the only factor in the digestion of fats—the nature and condition of the fatty acids may be of considerable importance. Also to be kept in mind is the interconversion of proteins via carbohydrates to fats and fats to carbohydrates in an animal (Bloor 1943, pp. 59, 61–62, 237–239).

In insects there is, also, considerable evidence that the synthesis of fats from carbohydrates and proteins occurs (Scoggin & Tauber 1950). Melampy & Maynard (1937) concluded that the German roach could convert proteins into lipids; and for the same insect McCay (1938) found that adults reared on a skim milk whole wheat diet, contained three times as much lipid as the ingested foodstuff. Schweet (Scoggin & Tauber 1950) concluded that the American roach could synthesize fat from protein although to a lesser extent than from carbohydrate. German roaches on different diets (Melampy & Maynard 1937) with the iodine numbers of the diet fats 7, 27, and 49 produced tissue fats with the iodine numbers of 51, 59, and 64 respectively. For the influence of diets on the fats of other insects, the interested reader may consult the review of Scoggin and Tauber.

Even in warm blooded animals the chemical nature of the stored fats is influenced to some extent by the environmental temperature. Zummo (1932) kept white rats at temperatures of 0° C. and 30° C. and found that the iodine number of the reserve fats decreased with the time of exposure to the higher temperature. Also the iodine numbers at both temperatures seemed to be influenced by the diet. According to the data about 15 days after rats were placed on a given diet at a given temperature they came to a level of lipid saturation and thereafter showed little change. The pioneer work of Henriques & Hansen (1901) correlates the iodine number and melting points of fats from different locations in the pig with the temperature of the regions from which the fats were taken. Dean & Hilditch (1933) confirmed and extended this work but at the same time in reviewing the literature they concluded that the general statement that warm blooded animals and plants of tropical regions produced more solid saturated fats than cold blooded animals or plants from cooler regions is only partially true. Lovern (1938) working with the eel, *Anguilla vulgaris*, found that a low fat diet caused no change in the fats of the animal, but a high fat diet exerted a not too clear influence which the investigator suggested was probably affected by temperature. Lovern also reported that Brockley and Bailey found increasing values for the iodine numbers of the fats of salmon as they went further north but only if the same species of salmon was considered.

Only a few investigations of the relationship of temperature and the lipids of insects have been made. Ackerman (1926) reared an aphid, *Rhopalosiphum prunifoliae*, at different temperatures and noted that the solidification point for fat globules in the body fluid increased with increase in rearing temperature. Rainey (1938) found the iodine numbers of blowfly larvae, *Lucilia sericata* to be 75.8 at 15° C., 72.7 at 25° C. and 71.1 at 35° C. Ditman and Weiland (1938) found some differences in the iodine numbers of the lipids of the corn ear worm, *Heliothis armigera* (Hub.); prepupae from insects reared at 78–88° F. had lipids with an iodine number of 70.7, and 85–99° F. the iodine number was 65.8. The iodine values for the phosphatides of the bluebottle fly, *Calliphora erythrocephala* (Meig.) and a sheep blowfly, *Phormia terra-novae* R. D. undergo quite a fall with rise in temperature (Fraenkel and Hopf 1940). Iodine numbers (averaged from the data of Fraenkel & Hopf) are 91 at 18° C., 75.6 at 27° C., and 65.5 at 36° C. for *Calliphora* and 85.2 at 12° C., 77.2 at 27° C., and 70.4 at 30–31° C. for *Phormia*.

There is a viewpoint with regard to lipids which enters into the present investigation. In selecting the phosphatides, Fraenkel & Hopf were choosing for in-

vestigation the lipids generally considered to be of more vital importance, that is to say, those which enter more directly into protoplasmic and cellular organization, and were thereby avoiding any differences which might be attributable to selective utilization of stored lipids. This differentiating concept of the stored lipids being more or less variable in character and quantity and the phosphatides being more or less constant in quantity and quality dates back to the work of Mayer and Schaeffer in 1914; these authors found that overfeeding or inanition did not greatly modify the lipid phosphorous content of organs (Bloor 1943, pp. 247–250). While the vital role of the constant element or specific organ lipids is in no way a matter of disputation, one may well think that the differences between these and the reserve fats have been overstressed to create the conception on one set of lipids playing a vital protoplasmic role and another set being held in reserve to await the time when some emergency would necessitate its mobilization as an energy source. In contrast to this concept Schoenheimer and his associates (1940) have by the study of the metabolism of the white rat by use of tracer substances produced rather startling revelations. Fatty acids are freely and continuously interconverted, oleic from stearic, palmitoleic from palmitic but linoleic and linolenic do not seem to be formed by desaturation. Lengthening and shortening of the carbon chain apparently occurs with ease. These processes occur not only in the neutral fats but in the phospholipids. The fats in a liver may mostly have been formed within the last day; there is a constant and rapid turnover.

Various theories have been proposed to account for the death of organisms exposed to unfavorably high temperatures. One of the more inviting of these has to do with the lipids of the cells. Heilbrunn (1924) working with *Arbacia* eggs described a heat coagulation other than protein coagulation and this occurred at lower temperatures than protein coagulation. This heat coagulation was apparently in someway associated with some change in the state of the fatty materials of the cells as it was increased by low concentrations of ether. Heilbrunn pointed out the correlation between the melting point of the lipids of organisms and the sensitivity of these organisms to heat. Bělehrádek (1931) extended these observations.

While many experiments on the acclimtization of animals have been performed, still very little has been done by laboratory experiment to test the role of lipids in thermic injury. In their well designed and executed work published in 1940, Fraenkel & Hopf set out to test the 'lipoid liberation' theory, that is the theory that heat injury whether reversible or irreversible is caused by the melting of the lipids in the cells or cell membranes. As cited above these investigators found that blowfly larvae reared at higher temperatures had phosphatides more saturated (lower iodine numbers) than those reared at lower temperatures. Moreover, those reared at lower temperatures seemed less resistant to high lethal temperatures. The authors concluded that blowfly larvae reared at higher temperatures not only become more resistant to killing temperatures but the melting points of the fats in their cells is adapted; and the authors suggest that while the results lend support to the 'lipoid liberation' theory, death at moderately high temperatures hardly is due to a mere melting of protoplasmic lipids, although such may, as it were, trigger a sequence of events. Using larvae of the same two species of flies in a subsequent investigation Hopf (1940) found that in both species when subjected to high temperatures there was an increase in the lipid phosphorous, the inorganic phosphorous, and in the adenylpyrophosphate phosphorous in the hemolymph. He concluded that the changes which he described represented an adaptation of the organism toward a change in its environmental conditions.

Heilbrunn, Harris, and Lefevre (1946) have presented strong evidence that in the vertebrate heated tissues may liberate toxins which cause changes in tissues at a distance. The toxins seem to be thrombin like and possibly interfere with the sodium/potassium ratio. At present there is no evidence that such a toxin may be liberated in an insect.

EXPERIMENTAL INVESTIGATION.—American roaches kept in aquaria were used in these experiments. These insects were fed "Milkbone" dog biscuits manufactured by the National Biscuit Company. Ac-

cording to the manufacturer's analysis these biscuits are low in fat: "minimum crude fat 1.50 per cent". Six samples of these biscuits taken from six different cartons were analyzed for the iodine number of the fats using the procedures given below. All the values obtained were near the mean of 74. No other analysis of the food was made.

The room in which the stock colony of roaches was kept became very warm occasionally in summer. However, with the advent of cooler autumn weather it was possible to maintain a relatively constant temperature (±2° C.) as desired by means of a thermostatically controlled electric heater. A "cool" refrigerator set at 17° C.±1 and a "warm" box made from an old refrigerator by the installation of an electrical heating unit controlled by a very sensitive (within 1°C.) thermostat were available for controlled temperatures

Groups of roaches used in the experiments were maintained under the indicated conditions and during periods of storage were kept in battery jars well supplied with food and water. About thirty roaches were in each jar and these were always at the beginning of the experiment nymphs, weighing not less than 400 mg. by estimate as in the determination of the iodine numbers no insects weighing less than 500 mg. were used. As large nymphs were placed in the different groups a few of them had become adults by the time the analyses were made. In general adults were not used in the experiments; the few cases in which they were used are so indicated.

Roaches used for total lipids were weighed, killed with boiling alcohol, minced with dissecting scissors, ground with fat free sand in a mortar; and the lipids were extracted by boiling the sand and tissues in alcohol, filtering and washing the residue with hot alcohol and with hot alcohol and ether. The filtrate was evaporated to near dryness on a water bath and the residue taken up with ether and filtered. Care was taken to avoid oxidation of the fats. The ether was evaporated off by agitating the tubes containing the lipid ether solution in warm water. Thus the sample of fat was obtained.

The iodine numbers of the lipids were obtained by the Wijs method as outlined by Jamieson (1934).

Eight experiments on lipid determinations were run but later, as further information for the iodine number at 31° seemed desirable, a ninth run was made.

Experiment 1. This was in someways a preliminary and exploratory experiment. Three groups of roaches were used: Group A was stored at 34° C., group B at room temperature, and group C at 17° C. The previous history of the roaches had been one of high room temperature and during the course of the experiment the room temperature was about 31° C. and, undoubtedly, had been this high for several days previous to this experiment as the room stayed at a high temperature generally. The original idea was to let the B group of roaches as "room temperature roaches" be subjected to fluctuating temperature conditions. Two days before the first analyses were run for this experiment this idea was abandoned; the laboratory radiator was turned off and the thermostatically controlled heater was turned on with the thermostat set at 27° C. In effect all three groups had been at a high temperature of about 31° C. for many days before the groups were set up and except for the last two days group B continued at this temperature for experiment 1; but groups A and C were at the temperatures of 34° C. and 17° C. respectively. At the end of 1 week three lots from each of the three groups were killed, their lipids extracted, and the iodine numbers determined. The lots, weights, sexes, instars, and iodine numbers for these and all other iodine number determinations are shown in table 1. In this first experiment, especially in group A the groups were mixed nymphs and adults. In subsequent experiments except for a few determinations such mixed groups were avoided.

Experiment 2. The A at 34° C., B at 27° C., and C and 17° C. groups of experiment 1 were continued for another week after which three lots were taken from each group and the iodine numbers determined.

Experiment 3. The above groups were continued for a third week, divided into lots and the iodine numbers determined.

Experiment 4. The iodine numbers of five lots of roaches held at 29° C. for 2 weeks were determined. Their previous temperature had been 23° C. for several weeks.

Experiment 5. The roaches previously at 23° C. for over three weeks were kept

at 30° C. for two weeks and the iodine number of their lipids determined.

Experiment 6. A group of roaches previously at a temperature of 32 ° C. for several weeks were kept at 39° C. for 12 days, were subdivided into four lots for which the iodine numbers of the lipids were determined.

Experiment 7. This experiment was undertaken to determine the iodine number of the lipids from roaches held at 23° C. for over 4 weeks.

Experiment 8. A group of roaches were submitted to a rather erratic diurnal variation; the nights being spent at 17° and the days being passed at 34° C. It came out that a total of 5.86 days were spent at the higher temperature, 7.28 days at the lower temperature. Previous to treatment these roaches had been at a temperature of 27° C. for 2 weeks. The group of roaches was divided into six lots for which the iodine numbers of the lipids were determined.

In order to confirm the result of experiment 1B the iodine numbers of the lipids of roaches held at 31° C. for 2 or 3 weeks were determined. The values of these two experiments are combined for the value for 31° C. in figure 1.

At the outset more emphasis was placed on rapidly securing a representative sample of fats for iodine number determination. Later, however, it was realized that a determination of the quantity of lipids might be of use and an attempt was made to secure this value. For roaches at or above, 23° C. for two weeks or longer the mean for 17 determinations for male nymphs gave a mean value of 6.6 ± 1.4; ten determinations for female nymphs gave a value of 6.8 ± 1.9. The difference in the two means is 0.2; the standard error of the difference is 0.723. Unfortunately the only values available for roaches at 17° C. are those made early in the investigation. These are low.

Five experiments on the resistance of roaches to high temperatures were run.

Experiment 10. This was a preliminary investigation. Seven nymphs which had been kept at 34° C., Group A, for 3 weeks and seven nymphs that had been kept at 23° C. for about 5 weeks were placed in shell vials covered at the end with wire mesh. Four roaches from the A group and three from the B group were placed alternately in the sliding tray of a Columbia paraffin oven. The tray was moved into place and the door partially closed so as to leave an aperture about 1 inch wide through which the roaches could be observed. The temperature in the oven as indicated by the thermometer rose rapidly to 66° to 68° C. Suddenly and simultaneously the three roaches of group B went into violent activity; the group A roaches remained only mildly active for about 30 seconds longer, then these four became violently active. Then the activity of roaches of both groups gradually abated with the onset of heat rigor with no manifest difference between the two groups. Under this setup it was not possible to watch the roaches, the temperature and the time very well, but the average time for cessation of motion was slightly less than 10 minutes from the time the insects were put into the oven. The four remaining roaches of group B and the remaining roaches of group A were treated similarly; and the same phenomenon was observed. Three roaches of each group recovered slightly but were discarded next day.

Experiments 11 through 13. A and B group roaches which had been conditioned at different temperatures were used. These animals were placed in 125 cc. Erlenmeyer flasks closed with a wire mesh cap. One roach was placed in each flask. In all these experiments A and B group roaches alternated both within and between rows arranged on the middle shelf of a thermostatically controlled, electrically heated oven, which in addition to the outer door had an inner door of glass through which observations could be made. Although the oven heated moderately rapidly and the thermostat was sensitive, there was no fan to distribute the heat so the temperature may not be regarded as even throughout the oven. Nevertheless, the arrangement of the flasks and the fact that in different experiments the group A and B roaches were shifted in relative position, provided comparable treatment for the two groups. The temperature inside the oven was read from a thermometer lying beside the front row of flasks. Nymphs were used in all experiments except experiment 14 in which young adults were used. Approximately half the number of roaches in each A and B group were male and the others female. Data for experiments 11 through 14 are given in table 2.

Table 1.—Iodine numbers for lipids extracted from the roach.

Exp. No.	No. Males	Roaches[1] Females	Ave. Wt. in mg.	Temp. °C.	Time at Temp.	Iodine No.	Ave. for Lots
1A	3, 3A	3, 1A	750	34	1 wk.	62.5	
	4	4, 2A	750			61.1	
	4	2, 2A	725			55.8	59.1
B	4	5, 1A	680	ca.	many wks.	57.7	
	4	6	750	31		60.9	
	6	4	750			55.8	58.1
C	4	6	770	17	1 wk.	63.2	
	7	3	720			61.4	
	6	4	710			65.8	63.5
2A	5A		680	34	2 wks.	57.6	
	5		740			62.3	
		5	720			60.5	60.1
B	5		700	27	12 days	74.2	
	5		700			72.0	
		5	740			63.7	68.0
C	5		660	17	2 wks.	71.6	
	5		740			72.3	
		5	720			70.7	71.2
3A	5		800	34	3 wks.	58.5	
	2, 2A		800			63.0	
		6	750			64.9	62.1
B	5		760	27	19 days	71.8	
		5	780			72.7	
		5	780			69.5	71.3
C	5		640	17	3 wks.	69.9	
		5	780			74.2	
		3	700			77.3	73.8
4	5		840	29	2 wks.	67.7	
	5		880			68.7	
	5		860			67.1	
		5	800			67.9	
		5	840			66.7	67.6
5	5		820	30	2 wks.	64.2	
	5		840			64.2	
	4		880			61.8	
		5	800			67.3	
		5	920			64.6	
		3	930			67.5	64.9
6	4A		810	39	12 days	55.5	
		4	610			56.5	
		4A	1050			63.2	
		4A	1200			52.7	57.0
7		1	985	23	4 wks.	75.1	
	1		710			72.3	
	1		945			66.0	
	1		680			71.4	
	1		560			72.9	
		1	720			67.7	
	1		835			69.6	
	1		670			66.9	
		1	560			69.0	
	1		540			68.0	70.0
8	5		800	17 & 34	alter. ca.	68.3	
	5		780		2 wks.	62.6	
	5		720			65.5	
	5		760			69.3	
		5	740			72.4	
		5	760			69.7	68.1
9	1		730	31	2 wks.	71.4	
	1		715			61.5	
		1	715			58.1	
		2	795	31	3 wks.	56.5	
	3		540			50.3	
		2	875			58.8	59.4

[1] A = Adults, otherwise Nymphs.

Table 2.—Mortality at different high temperatures of roaches previously exposed to different storage temperatures.

EXP. NO.	GROUP	STORAGE TEMP. °C.	TIME AT STORAGE WKS.	TREATMENT TEMP. °C.	PERIOD OF TREATMENT MINS.	NUMBER OF ROACHES	NUMBER KILLED
11	A	34	3	ca. 43	29	5	2
	B	23	3	ca. 43	29	5	2
12	A	34	3	ca. 45	50	9	8
	B	23	3	ca. 45	50	9	8
13	A	34	2	ca. 43	35	11	5
	B	23	8	ca. 43	35	11	4
14	A	34	3	ca. 41	210	11	9
	B	23	8	ca. 41	210	11	11

ANALYSIS AND DISCUSSION OF RESULTS.—The lipids obtained by the procedure outlined above were a viscous straw-colored oil. Timon-David described the oils extracted from the oriental roach as having a pungent odor; these lipids from the American roach had only a faintly detectable odor. No determinations of solidification as such were run but it was noted that at about 22° C. the oils with the lower iodine numbers showed some indications of setting.

Immediately after the iodine numbers in the three groups in experiment 1 were determined it was seen by means of these values that if different temperatures were to produce significant differences in the iodine numbers of the lipids, longer periods of exposure to the temperatures were required, although group C was somewhat higher than the other groups. Thus the three groups were continued at their respective temperatures and the determinations of experiments 2 and 3 were made. While the group B and C roaches show a rise in iodine numbers, the group A roaches within experimental error do not, but remain essentially at the level produced by the pretreatment room conditions (about 31° C. for several weeks). Although it seemed obvious by inspection that the A groups of experiments 2 and 3 were different from either the B or C groups; it was, indeed questionable whether the B and C groups might differ from each other. By calculation the combined A groups gave a mean of 61.0 with a standard deviation of the mean (computed for small numbers) of 1.08; for the combined B groups 70.7 and 1.52; for the combined C groups 72.7 and 1.16. Comparing the three groups by the standard error of the difference between two means confirmed the conclusion that the A groups were extremely different from the B and C groups; but that the latter were not statistically different from each other.

The conclusion is then obvious: between 17° C. and 27° C. the degree of saturation of the total lipids of the roach under the same conditions is the same and between 27° and 31° C. there is a rapid fall in the iodine number.

The iodine numbers for the B and C groups show a steep rise during the first and second weeks and a leveling off (exper. 3) between the second and third week thus indicating an approach to a dynamic stabilized condition at about the end of the second week. Experiment 8 in which the roaches were fluctuated alternately at 17° and 34° C. indicates the same rate. These insects having been for several weeks at a temperature of 27° C. before the treatment began would have had an iodine number of about 72. Had they been kept for 2 weeks at 34° C. their expected iodine number would have been about 60. As it worked out a summation of the total number of hours spent at the 34° C. temperature was slightly less than 6 days and their mean iodine number of 68.1 is within experimental error what one would expect if the roaches had simply been stored at 34° C. for about 6 consecutive days. Aside from confirming the rate of change over, experiment 8 establishes that the mechanism by which the iodine numbers are altered is quickly responsive to change in temperature and, moreover, is thrown into and out of operation each time the temperature falls or rises. A

single brief exposure does not take the iodine numbers from one level to the other, in other words there does not seem to be a "triggered" reaction.

The data of Zummo (1932) with white rats also indicates that a shift in iodine numbers seems to be completed in about twelve to fifteen days. This, with the observation above is of considerable theoretical interest. If storage lipids in an animal are to be considered as sharply set aside from the protoplasmic lipids there seems to be little reason why their iodine numbers should change. The rather rapid shift in the numbers may be interpreted to be in line with the concept of Schoenheimer that all the materials in an animal are in a constant state of flux.

In order to determine more completely the response of the lipids to temperatures between 17° and 27° C., between 27° C. and 31° C. and above 34° C. experiments 4, 5, 6, 7, and 9 were run. The arithmetic means for these experiments with the arithmetic means from the groups in experiments 2 and 3 properly combined are plotted in figure 1.

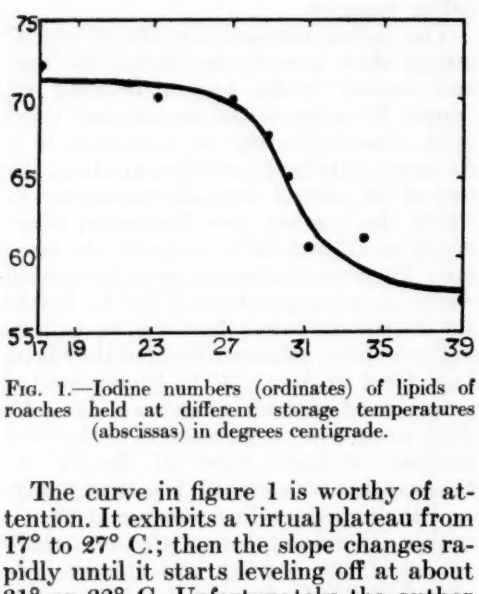


FIG. 1.—Iodine numbers (ordinates) of lipids of roaches held at different storage temperatures (abscissas) in degrees centigrade.

The curve in figure 1 is worthy of attention. It exhibits a virtual plateau from 17° to 27° C.; then the slope changes rapidly until it starts leveling off at about 31° or 32° C. Unfortunately the author found in the literature no data with which this curve might be compared. The data of Henriques and Hansen deals with different sites within an animal and is not comparable; Zummo kept his rats at two extreme temperatures. The data of Fraenkel & Hopf while consisting of a considerable number of iodine number determinations can not be used for comparison as these are distributed among two insects and two methods, and thereby do not provide over three points for any one animal for one method. The selected temperatures include one low, one medium, and one high; and lines connecting the iodine values for these might be considered as a straight line or only mildly curving. If only the values of 17°, 30° and 39° C. in figure 1 are considered they could be interpreted as lying on a straight line.

The nature of the curve is such as to invite discussion. Perhaps it may be the result of the differential absorption of food fats dependent on temperature; but considering the low fat content stated to be in the dog biscuits (not less than 1.5 per cent according to the manufacturer; actually giving for six samples a mean of 2.5 per cent by analysis of this author) and the fact that this food fat ran iodine numbers higher than those obtained on the average at any temperature from the roaches one is inclined to reject an explanation of differential absorption. The form of the curve is perhaps more suggestive of an enzyme optimum. It might be postulated that the animal is forming hard fats from the carbohydrates in its diet and that these fats are being desaturated at temperatures around 30° C. and below by a dehydrogenase system. The answer will have to wait for more data; conjecture is hardly warranted at the present time.

Some incidental observations may be made. In table 1 it may be seen that the determinations for males and females vary at random. As the iodine numbers for 17°, 23° and 27° are statistically equivalent the determinations for the sexes in experiments 2 B and C, 3B and C and 7, legitimately, may be grouped for comparison. For 11 determinations involving males the mean is 71.9; for an equal number of determinations for females it is 70.0. Thus within experimental error of the determinations no difference is shown. The few iodine numbers involving adults in table 1 are mostly for mixed groups, but the few exclusively adult values do not seem to differ from those for nymphs. However, these were very young adults, perhaps, in no case were any of them over a week old.

In experiment 7 exceedingly great care was taken to obtain all the lipids as each determination of the iodine number was based on a single animal. It may be seen by table 1 that the iodine values for individual roaches in this experiment do not vary much more than those for pooled values in other experiments even though the quantity of lipid for each determination was less than should generally be used. The values obtained however indicate that the variation in these experiments is probably more a matter of technique than of actual biological variation in the insects.

Experiment 7 may be considered to have given relatively good measures of the total quantity of lipids. The mean value for the 10 nymphs is 7.7 per cent of wet weight. The seven males averaged 7.1; the three females 8.9. While 7.7 per cent is perhaps as near the true value for nymphs as the 6.6 or 6.8 given above for males and females as determined by several experiments including No. 7 it is doubtful that the sex difference is as great as experiment 7 would tend to indicate, for while the values 6.6 and 6.8 are probably somewhat low the error induced in them by the technique of their extraction should not have obscured any sex difference. While the 8.9 per cent value is somewhat lower than the highest value given for the female American roach adult (by Schweet) the value 6.6 above exceeds all other values for roaches found in the literature. These figures are in line with those reported for other Orthoptera.

In this investigation it was not intended to study the influence of temperature on rate of growth or development; but it was qualitatively noticeable that the roaches at higher temperatures matured much more rapidly than the roaches at lower temperatures. For example, although they, presumably, were on the average of the same weight and age at the time the experiments began the roaches in groups A and C in experiments 1, 2, and 3 developed at quite different rates. In the three week period in which they were stored 15 out of 30 roaches in the A groups moulted to adults; in the C groups none, as adult roaches seem to lose weight near the last moult the A groups only slightly outweigh the C groups; the B groups in experiments 2 and 3 do seem to slightly outweigh the C groups. Moreover the roaches at 17° C. were in general sluggish and ate very little food.

While the preliminary observations in experiment 10 indicated some difference in the reaction of roaches with different iodine numbers to unfavorably high temperatures the more definite data in table 2 indicate no differences. In all the experiments the few surviving roaches appeared to be about equally seriously injured and roaches of comparable A and B groups were indistinguishable by their symptoms. While the conditions of these experiments might have been improved by the ovens having a circulating fan, still conditions for the compared groups were essentially the same. Therefore, on the basis of these experiments it must be concluded that no wide margin of difference existed and that an iodine number difference of about ten digits in the total lipids of the American roach does not appreciably influence the ability of this animal to withstand temperatures sufficiently high to be lethal; nor did two or three weeks afford any "acclimatization."

SUMMARY AND CONCLUSIONS.—Total lipids have been extracted from the nymphs of the American roach stored at different temperatures and the iodine numbers for these lipids determined.

Between 17° C. and 27° C. iodine numbers range around 72 and show no statistical difference; between 27° C. and about 32° C. the iodine numbers fall rapidly to around 60 and show little further decline with increase in temperature up to 39° C.

When shifted from a suitably high to a suitably low temperature, or vice versa, the alteration of the iodine numbers appears to be approximately complete in about two weeks. This rate of change is consistent with the idea of Schoenheimer that the lipids in an animal are in a constant state of flux.

The shift from one iodine number level to another under the stimulus of temperature change, apparently, is not a "triggered" reaction.

Male and female nymphs show little, if any, difference in the quantity of their total lipids, the amount being somewhat more then 6.6 per cent of wet weight. This value and others reported and discussed in this paper is in line with those for other insects including other species of roaches reported in the literature.

As an incidental observation it was

noted that the roach nymphs mature much faster at the higher than at the lower temperatures.

Groups of roaches, stored for a time interval sufficiently long to insure different iodine numbers for different temperatures, show no difference in their resistance to high lethal temperatures under the experimental conditions of this investigation. This investigation while in no sense disproving a possibly very vital role of the lipids in the resistance of animals to high temperature, does not lend support to the 'lipoid liberation' theory.

ACKNOWLEDGMENT: The author wishes to express his appreciation to Dr. E. N. Cory, Professor of Entomology, the University of Maryland, for his kindness and understanding during the past few years, and especially for his encouragement during the period in which the above research was accomplished.

LITERATURE CITED

Ackerman, L. 1926. The physiological basis of wing production in the grain aphid. Jour. Expt. Zool. **44:** 1–61.

Bělehrádek, J. 1931. Le mécanisme physiochemique de l'adaptation thermique. Protoplasma **12:** 406–34.

Bloor, W. R. 1943. Biochemistry of the fatty acids and their compounds, the lipids. 387 pp. Amer. Chem. Soc. Monograph Series. Reinhold Pub. Co. N. Y.

Dean, H. K. and T. P. Hilditch. 1933. The influence of body temperature on the composition of depot fat. Biochem. Jour. **27:** 1950–6.

Ditman, L. P. and G. S. Weiland. 1938. Metabolism in the corn earworm. I. Studies on fat and water. Md. Agr. Expt. Sta. Bul. **44:** 83–206.

Fraenkel, G. and H. S. Hopf. 1940. The physiological action of abnormally high temperatures on poikilothermic animals. Biochem. Jour. **34:** 1085–92.

Heilbrunn, L. V. 1924. The colloid chemistry of protoplasm. IV. Heat coagulation of protoplasm. Am. Jour. Physiol. **69:** 190–9.

Heilbrunn, L. V. 1947. An outline of general physiology. 2nd ed. rev. 748 pp. W. B. Saunders and Co., Phila.

Heilbrunn, L. V., D. L. Harris, and P. G. Lefevre. 1946. Heat death, heat injury, and toxic factor. Physiol. Zool. **19:** 404–29.

Henriques, V. and C. Hansen. 1901. Vergleichender untersuchungen über die chemische zusammensetzung des tierischen fettes. Skand. Arch. Physiol. **11:** 151–65.

Hopf, H. S. 1940. The physiological action of abnormally high temperatures on poikilothermic animals. 3. Some changes occurring in the phosphorus distribution in the haemolymph of insects under the influence of abnormally high temperatures. Biochem. Jour. **34:** 1396–1403.

Jamieson, G. S. 1943. Vegetable fats and oils. 508 pp. Amer. Chem. Soc. monograph No. 58. 2nd. ed. Reinhold Pub. Corp., N. Y.

Lovern, J. A. 1938. Factors influencing the composition of depot fat in fishes. Biochem. Jour. **32:** 1214–24.

McCay, C. M. 1938. The nutritional requirements of *Blatella germanica*. Physiol. Zool. **11:** 89–103.

Melampy, R. M. and L. A. Maynard. 1937. Nutritional studies with the cockroach (*Blatella germanica*) Physiol. Zool. **10:** 36–44.

Rainey, R. C. 1938. On the changes in chemical composition associated with larval development in the sheep blowfly. Ann. Appl. Biol. **25:** 822–35.

Schoenheimer, R. and D. Rittenberg. 1940. The study of intermediary metbaolism of animals with the aid of isotopes. Physiol. Rev. **20:** 218–48.

Scoggin. J. K. and O. E. Tauber, 1950. Survey of literature on insect lipids. Iowa State Col. Jour. Sci. **25:** 99–124.

Timon-David, J. 1930. Recherches sur les matieres grasses des insectes. Ann. Faculté des Sci. Marseille. Ser. 2, **4:** 29–207.

Zummo, C. 1932. Grassi di deposito e loro variazione in rapporto alla temperatura ambiente. Arch. di fisiol. **31:** 347–54.

Fall Migration of Aphids with Special Reference to the Green Peach Aphid[1]

J. H. Newton, M. A. Palmer and George M. List, *Colorado Agricultural Experiment Station, Fort Collins*

Stone fruits are known to be subject to a number of serious virus diseases. The importance of aphids in the transmission of plant viruses makes their presence and habits in an intensive stone fruit producing area a matter of importance. Evidence presented by Daniels (1945, 1948) indicates that the green peach aphid, *Myzus persicae* (Sulzer), is probably the number one agent in the natural spread of the peach mosaic. Therefore, habits and host plant relationships of this species are of special importance. The new approach to the control of this species through the use of fall applications of residual insecticides (Newton & List 1947) emphasized the need for detailed information on the movement from summer hosts to winter hosts from the practical standpoint of timing of the spray applications. Such a study was made at Palisade, Colorado, during the falls of 1946 and 1947.

Materials and Methods.—Sticky trap boards prepared according to specifications made by Kaloostian & Yeomans (1944) for pear psylla, *Psylla pyricola* Foerst., scouting work were employed. Funds for the purchase of some 1100 of these boards came from the Mesa County Research Committee. One trap was hung by a wire about mid-height in each tree in such a manner that it could swing freely. After exposures of from 3 to 8 days the traps were removed and all aphids carefully collected, washed in alcohol to remove the tangle-foot, then mounted for identification. In 1946 one trap was placed in each of five trees in 26 peach orchards representing natural regions in the Palisade area. During 1947 one trap was placed in each of five trees in 11 orchards similarly selected.

Results.—Tables 1 and 2 give the total aphids by species taken from the traps and the periods of first, last and maximum trapping. Approximately 6.3 per cent of the specimens were unidentifiable because of breakage. It will be noted that a total of 44 species, representing 18 genera were identified during the two seasons. Each year 31 species representing 15 genera were identified. A total of 2287 aphids were taken during the two fall migrating seasons, 1958 of these were viviparae and 323 males. The viviparae outnumbered the males a little more than 6 to 1. In only one species where any considerable number was taken, did the males outnumber the viviparae; this occurred with the green peach aphid in 1947. With all species where males were taken, the viviparae were migrating earlier than the males. With the green peach aphid, viviparae were taken over a period of 48 days in 1946 and over a period of 14 days in 1947, before males were taken. This, especially in 1946, gave sufficient time for the viviparae to give rise to the egg laying females and for these to become sexually mature before the males appeared from the summer hosts. During the two seasons 126 *Anoccia querci* (Fitch), 88 *Eriosoma lanigerum* (Haus.), and 49 *Pemphigus balsamiferae* Williams viviparae were taken but no males, since in these species the males are apterous and are deposited by the viviparae on the winter host. The length of time over which migration took place was, with most species, longer than expected. In 1946 three species were trapped during the period of December 9 to 18. The green peach aphid showed the greatest late activity. However, this is not to the advantage of the species in that the late viviparae fail to give rise to egg-laying females or the latter have insufficient time to mature before leaf fall.

Discussion.—The green peach aphid was the only species that successfully colonized on the peach and produced mature egg-layers. However, this does not preclude the possibility of others feeding sufficiently to transmit a virus. The viviparae of *Amphorophora sonchi* (Oestlund) were observed to produce colonies of egg-layers on peach foliage in 1946 but careful observations failed to show deposition of overwintering eggs. There are, in the Colorado Agricultural Experiment Station collection, one apterous egg laying female of

[1] Scientific Journal Series Paper No. 402, Colorado Agricultural Experiment Station.

Table 1.—The species of aphids taken as fall migrants on tanglefoot traps in peach orchards, Palisade, Colorado, 1946, with periods of first, last, and maximum trapping.

Species Taken	Periods of Trapping							
	Period First Trapped		Period Last Trapped		Period Greatest No. Trapped		Totals	
	V[1]	M[2]	V	M	V	M	V	M
Amphicercidus flocculosus (Gillette & Palmer)	9/10–17		9/10–17		9/10–17		1	
Amphorophora sonchi (Oestlund)	9/3–10	10/6–21	11/22–12/2	11/22–12/2	9/26–10/6	10/6–21	95	3
Anoecia querci (Fitch)	9/10–17		10/21–30		9/26–10/6		65	
Aphis bakeri Cowen	9/3–10	9/17–26	12/9–18	12/2–9	9/26–10/6	12/2–9	118	6
Aphis crataegifoliae Fitch	9/3–10	9/3–10	12/2–9	11/16–22	9/10–17	11/15–22	89	4
Aphis helianthi Monell	9/3–10		9/26–10/6		9/10–17		24	
Aphis rosea (Baker)	9/10–17	10/21–30	10/30–11/7	10/21–30	10/6–21	10/21–30	3	1
Aphis rumicis (Linn.)	9/10–17		10/6–21		9/26–10/6		9	
Aphis viburnicola (Gillette)	9/10–17		9/26–10/6				2	
Aphis vorabonnevilla Knowlton	9/10–17		11/7–15		9/26–10/6		29	
Aphis sp.	9/10–17		10/6–21		9/26–10/6		18	
Brevicoryne brassicae (Linn.)	9/26–10/6		9/26–10/6		9/26–10/6		1	
Eriosoma laniyerum (Hausmann)	9/3–10		10/6–21		9/17–26		46	
Hyalopterus sp.	9/3–10		9/3–10		9/3–10		1	
Macrosiphum dirhodum (Walker)	9/17–26		11/22–12/2		9/17–26		4	
Macrosiphum granarium Kirby	9/10–17		9/10–17		9/10–17		1	
Macrosiphum pisi (Kalt.)	11/15–22		11/15–22		11/15–22		1	
Myzus lythri (Schrank) or *mahaleb* Koch	9/10–17	10/6–21	9/26–10/6	10/6–21	9/26–10/6	10/6–21	33	1
Myzus persicae (Sulzer)	9/3–10	10/21–30	12/9–18	12/9–18	9/26–10/6	11/15–22	96	26
Pemphigus balsamiferae Williams	9/3–10		11/7–15		10/21–30		24	
Pemphigus sp.	9/3–10		9/10–17		9/3–10		8	
Prociphilus corrugatans (Sirrine)	9/3–10		9/3–10		9/3–10		1	
Prociphilus venafuscus Patch	9/17–26		11/15–22		10/21–30		17	
Pterocomma populifoliae (Fitch)	11/15–22	11/7–15	11/15–22	11/7–15	11/15–22	11/7–15	2	1
Pterocomma pseudopopulea Palmer	9/10–17		9/10–17		9/10–17		1	
Pterocomma smithiae (Monell)	9/26–10/6	10/21–30	11/7–15	11/22–12/2	10/6–21	10/21–30	24	4
Rhopalosiphum grabhami Ckl. or *poae* (Gillette)	9/10–17		9/10–17		9/10–17		1	
Rhopalosiphum maidis (Fitch)	9/3–10		10/6–21		9/10–17		41	
Rhopalosiphum nymphaeae (Linn.)	9/3–10	11/7–15	10/6–21	11/7–15		11/7–15	2	1
Rhopalosiphum prunifoliae (Fitch)	9/3–10	10/21–30	12/9–18	12/2–9	9/26–10/6		83	2
Unidentifiable	9/17–26	10/21–30	11/22–12/2	11/22–12/2	9/26–10/6	10/21–30	50	5
Total							890	54

[1] Viviparae. [2] Males.

Hyalopterus arundinis (Fab.) and three of *Rhopalosiphum prunifoliae* (Fitch) taken on peach October 27 and 29, 1936 by Max Sisson of the U. S. Bureau of Entomology and Plant Quarantine. At this same time Sisson took apterous viviparae of *Myzus cerasi* (Fab.) on Duke cherry, apterous egg layers of *Aphis helichrysi* Kalt, *Phorodon humuli* Schrank, *Rhopalosiphum prunifoliae* (Fitch) and *Hyalopterus arundinis* (Fab.) on plum and the latter on apricot.

Data indicate that the green peach aphid viviparae and egg layers avoid the mature leaves that are near dropping. Counts made October 17, 1951, cooperatively with Lorin Anderson of the Colorado Division of Agriculture, in an orchard being observed for the timing of fall experimental spray tests for peach aphid control showed the population on 100 yellowing and mature leaves taken at random to be 26 alates and 189 immature egg layers, while 100 green leaves in the same orchard carried 165 alates and 1040 immature egg layers. On this date no eggs could be found but many egg layers were near maturity as evidenced by an egg count made October 28, when 263 eggs were found on 100 buds selected at random. Also egg layers must have foliage upon which to feed to reach maturity. The time of leaf maturity and fall are, therefore, very important in determining the number of overwintering eggs. The apterous egg layers carried to the ground on falling leaves do not as a rule again reach the tree for egg deposition. Falls with early leaf drop have been noted to be followed by light aphid populations. This seems positive enough that early leaf fall through cultural methods and the use of chemical defoliators is suggested as a possible means of control.

From the standpoint of possible virus relationships the summer and winter hosts involved in this great fall movement of aphids are of major importance. The world host plant records compiled by Patch (1938) and Colorado collection

Table 2.—The species of aphids taken as fall migrants on tanglefoot traps in peach orchards, Palisade, Colorado, 1947, with periods of first, last and maximum trapping.

Species Taken	Periods of Trapping							
	Period First Trapped		Period Last Trapped		Period Greatest No. Trapped		Totals	
	V[1]	M[2]	V	M	V	M	V	M
Amphorophora sonchi (Oestlund)	9/15–20	10/7–19	11/7–15	11/7–15	9/22–29	10/7–19	149	23
Anoecia querci (Fitch)	9/15–20		10/31–11/7		10/19–25		61	
Aphis bakeri Cowen	9/15–20	10/7–19	10/31–11/7	11/7–15	9/22–19	10/7–19	78	12
Aphis cerasifoliae Fitch	9/20–22		9/20–22		9/20–22		2	
Aphis crataegifoliae Fitch	9/15–20	10/7–19	11/7–15	11/7–15	9/22–29	10/19–25	219	33
Aphis helianthi Monell	9/15–20	10/7–19	11/7–15	10/31–11/7	9/20–22		23	2
Aphis knowltoni Hottes and Frison	9/22–29		10/19–25				2	
Aphis rosea (Baker)	9/20–22	10/19–25	10/19–25	10/19–25	9/29–10/7	10/19–25	8	4
Aphis rumicis (Linn.)	9/22–29		10/19–25		10/19–25		5	
Aphis vorabonnevilla Knowlton	9/15–20	10/7–19	10/19–25	10/19–25	9/29–10/7	10/7–19	44	22
Brevicoryne brassicae (Linn.)	10/19–25		10/19–25		10/19–25		1	
Capitophorus braggii (Gillette)		10/7–19		10/7–19		10/7–19		2
Capitophorus gillettei Theobald		10/7–19		10/7–19		10/7–19		1
Capitophorus xanthii (Oestlund)	9/20–22		9/20–22		9/20–22		1	
Eriosoma lanigerum (Hausmann)	9/15–20		10/19–25		10/19–25		42	
Hyalopterus arundinis (Fab.)	9/15–20		9/20–22		9/20–22		3	
Macrosiphum barri Essig	9/22–29		9/29–10/7		9/29–10/7		4	
Macrosiphum dirhodum (Walker)	9/20–22		10/19–25				4	
Myzocallis californica Baker	9/20–22		9/20–22		9/20–22		1	
Myzus lythri (Schrank) or *mahaleb* Koch	9/15–20	10/7–19	10/19–25	10/19–25	10/19–25		13	6
Myzus ornatus Laing	9/15–20	9/29–10/7	9/29–10/7	9/29–10/7	9/15–20	9/29–10/7	4	4
Myzus persicae (Sulzer)	9/15–20	9/29–10/7	11/7–15	11/7–15	9/22–29	10/7–19	81	97
Pemphigus balsamiferae Williams	9/15–20		10/19–25		10/7–19		25	
Pemphigus monophagus Maxson	9/20–22		9/20–22		9/20–22		1	
Prociphilus venafuscus Patch	10/19–25		10/19–25		10/19–25		5	
Pterocomma smithiea (Monell)	9/29–10/7	10/7–19	10/31–11/7	10/31–11/7	10/7–19	10/7–19	9	17
Rhopalosiphum grabhami Ckl.	9/22–29		9/22–29		9/22–29		2	
Rhopalosiphum maidis (Fitch)	9/20–22		10/19–25		9/22–29		23	
Rhopalosiphum prunifoliae (Fitch)	9/15–20	10/7–19	10/29–31	11/7–15	9/29–10/7	10/19–25	162	40
Toxoptera graminum (Rondani)	9/20–22		9/29–10/7		9/29–10/7		8	
Toxoptera muhlenbergiae Davis	10/19–25		10/19–25		10/19–25		4	
Unidentifiable	9/22–29	9/29–10/7	10/31–11/7	10/31–11/7	9/22–29	9/29–10/7	83	6
Total							1067	269

[1] Viviparae. [2] Males.

records given by Palmer (1952) for those species that were represented by 20 or more specimens on the traps for any one season are given below. Colorado records are indicated by use of the asterisk. Plant names are according to Standardized Plant Names (1942).

HOST PLANT RECORDS.—

Amphorophora sonchi (Oestlund). Winter hosts: *Ribes aureum*, R. longifolium, R. nigrum**. Summer hosts: *Apium graveolens*, Lactuca* sp.*, Sonchus asper, S. oleraceus**.

Anoecia querci (Fitch). Winter hosts: *Quercus* sp., *Cornus amomum, C. florida, C. paniculata, C. sanguinea, C. stolonifera**. Summer hosts: *Andropogon scoparius, Aster ericoides, A. novae angliae, Digitaria sanguinalis, Eleusine indica, Erigeron philadelphicus, Muhlenbergia mexicana, Oenothera biennis, Panicum capillare, P. glabrum, P. virgatum, Phleum pratense, Poa pratensis, Polygonum erectum, P. hydropiper, Setaria glauca, S. viridis, Sorghum halepense, Solidago graminifolia, Zea mays,* roots of grasses* (species not specified).

Aphis bakeri Cowen. Winter hosts: *Crataegus rivularis*, Cydonia* sp.*, Malus* sp.*, Prunus* sp., *Pyrus baccata, P. communis**. Summer hosts: *Amsinckia, Capsella bursapastoris, Medicago sativa*, Melilotus alba*, Trifolium alexandrianum, T. incarnatum, T. pratense*, T. repens*, T. repens-latum.*

Aphis crataegifoliae Fitch. Winter hosts: *Crataegus coccinea, C. oxyacantha, C. punctata, Crataegus* sp.*, Cydonia japonica, C. vulgaris, Prunus* sp., *Pyrus communis, P. malus.* Summer hosts: *Lathyrus odoratus, Pisum sativum, Trifolium* sp.*

Aphis helianthi Monell. Winter hosts: *Catalpa* sp., *Cornus mas, C. sanguinea, C. stolonifera**. Summer hosts: *Ambrosia artemisiaefolia*, A. trifida*, Aster, Asclepias* sp.*, Carduus, Cirsium* sp.*, Helianthus annuus*, H. divaricatus, H. giganteus, H. grosseserratus, H. petiolaris*, H. rigidus, H. tuberosus, Iva xanthifolia*, Mirabilis linearis*, M. nyctaginea*, Urtica gracilis**.

Aphis vorabonnevilla Knowlton. Winter hosts: *Populus deltoides, P. angustifolia, Salix* sp. Fall migrants numerous on these plants—no eggs deposited, doubtful hosts. Summer hosts: Unknown.

Eriosoma lanigerum Hausmann. Winter hosts: *Ulmus americana, U. campestris, U. montana.* Summer hosts: *Cotoneaster acutifolia, C. horizontalis, C. humifusa, Crataegus coccinea, C. crusgalli, C. cuneata, C. rivularis, Cydonia* sp., *Malus* sp.*, *Malus floribunda, M. pumila, M. rivularis, M. sieboldii, M. toringo, Prunus, Pyrus americana, P. communis, P. malus, P. sitchensis, Sorbus* sp.

Myzus lythri (Schrank) or *mahaleb* (Koch). Winter hosts: *Lythrum salicaria, Prunus mahaleb**. Summer hosts: *Epilobium adenocaulon*, Galium* sp.*

Myzus persicae (Sulzer). This species has such a wide range of summer hosts that they are here recorded only by family. In many records, determination of the host is only to genus. Sixty-nine families are represented in the world records (Patch 1928), and 21 in Colorado records. The world records, ex-

clusive of Colorado records taken since 1938, indicate 235 genera and at least 335 species. The figures following family names indicate as accurately as can be determined the number of species and genera represented. Winter hosts: Mostly peach* and nectarine*, also *Prunus armeniaca**, *P. besseyi**, *P. cerasus**, *P. americana**, *P. domestica**, *P. japonica**, *P. virginiana**. Summer hosts: *Acanthaceae* 1-1, *Aceraceae* 2-1, *Aizoaceae* 1-1, *Apocynaceae* 3-2, *Amaryllidaceae* 3-3, *Amaranthaceae** 4-4, *Araceae* 2-2, *Araliaceae* 1-1, *Asclepiadaceae* 1-1, *Bignoniaceae* 2-2, *Boraginaceae* 4-4, *Cactaceae* 1-1, *Convolvulaceae* 7-3, *Cannaceae* 1-1, *Caprifoliaceae* 2-2, *Caryophyllaceae** 4-3, *Celastraceae* 1-1, *Chenopodiaceae** 9-5, *Compositae** 49-33, *Crassulaceae* 2-2, *Cruciferae** 29-17, *Cucurbitaceae** 5-3, *Dipsacaceae* 1-1, *Euphorbiaceae** 5-4, *Geraniaceae** 4-2, *Gesneriaceae* 1-1, *Gramineae** 7-6, *Iridaceae* 4-4, *Labiatae* 3-3, *Lauraceae* 1-1, *Leguminoseae** 14-12, *Liliaceae** 10-8, *Loganiaceae* 1-1, *Lythraceae* 1-1, *Malvaceae** 13-8, *Magnoliaceae* 1-1, *Marsileaceae* 2-1, *Myrtaceae* 3-3, *Nyctaginaceae** 1-1, *Oleaceae* 2-2, *Onagraceae* 5-2, *Orobanchaceae* 1-1, *Oxalidaceae* 3-1, *Papaveraceae* 1-1, *Pedaliaceae* 1-1, *Piperaceae* 1-1, *Pittosporaceae* 3-1, *Plantaginaceae* 1-1, *Polemoniaceae* 1-1, *Polygonaceae** 5-3, *Portulacaceae* 1-1, *Primulaceae** 1-1, *Ranunculaceae* 5-3, *Rosaceae** 33-11, *Rubiaceae* 1-1, *Rutaceae* 3-1, *Salicaceae* 1-1, *Sapindaceae* 1-1, *Saxifragaceae* 4-4, *Scrophulariaceae** 11-10, *Solanaceae** 21-9, *Thymelaeceae* 1-1, *Tropaeolaceae* 1-1, *Typhaceae* 1-1, *Umbelliferae** 7-5, *Urticaceae* 4-3, *Valerianaceae* 3-2, *Verbenaceae** 3-2, *Violaceae** 3-2.

Pemphigus balsamiferae Williams. Winter hosts: *Populus angustifolia**, *P. balsamifera*, *P. tacamahaca**. Summer hosts: *Beta vulgaris**, *Chenopodium alba**, *Achillea* sp.*, *Agropyron* sp.*, *Aster multiflorus**, *Cyloloma atriplicifolium**, *Lactuca sativa**, *Poinsettia* sp.*, *Polygonum aviculare**, *Solidago* sp.*

Pterocomma smithiea (Monell). *Populus alba*, *P. deltoides*, *P. grandidentata*, *P. occidentalis*, *P. sargenti**, *Populus* sp.*, *Salix alba*, *S. fragilis*, *S. nigra*, *Salix* sp.* Summer hosts: Same as winter hosts.

Rhopalosiphum fitchii Sanderson. Winter hosts: *Crataegus crusgalli*, *C. cuneata*, *Crataegus* sp.*, *Cydonia vulgaris*, *Cydonia* sp.*, *Malus floribunda*, *M. pumila*, *M. sieboldi*, *Malus* sp.*, *Prunus avium*, *P. communis*, *P. japonica*, *P. mume*, *P. persica*, *P. serrulata*, *Pyrus communis*, *P. sinensis*. Summer hosts: *Agrotis alba*, *Andropogon sorghum*, *Avena sativa**, *Allium* sp., *Carex* sp., *Dactylis glomerata*, *Eleusine coracana*, *Helianthus annuus*, *Hordeum vulgare*, *Oryza sativa*, *Panicum crusgalli*, *P. miliaceum*, *P. sanguinale*, *Phleum pratense*, *Poa pratensis*, *Secale cereale*, *Setaria italica*, *S. viridis*, *Triticum aestivum*, *T. vulgare**, *Zea mays*.

Rhopalosiphum maidis (Fitch). Only genera of host plants are here recorded. Figure following generic name indicates the number of species known to be hosts, where more than one species has been recorded. Winter hosts: No woody winter hosts recorded. Summer hosts: *Andropogon*, *Arundo*, *Avena**, *Ambrosia*, *Axonopus*, *Brasenia*, *Carex**, *Cynodon*, *Cyperus*, *Dactyloctenium*, *Digitaria* (5), *Echinochloa** (2), *Eleusine* (2), *Eragrostis*, *Eriochloe* (2), *Holcus*, *Hordeum** (2), *Leptochloa*, *Miscanthus*, *Muhlenbergia*, *Nymphaea*, *Oxalis*, *Panicum** (8), *Paspalum* (4), *Pennisetum*, *Phragmites*, *Plantago*, *Poa*, *Polygonum*, *Polytrias*, *Rottboellia* (2), *Saccharum* (2), *Scirpus*, *Secale*, *Setaria** (5), *Solanum*, *Sorghum** (3), *Sporobolus*, *Tripsacum*, *Triticum**, *Typha*, *Zea** (2).

SUMMARY.—During a study of the possible relationship of aphids to the spread of stone fruit virus, sticky board traps were operated during two fall seasons to study the migration from summer to winter hosts. Forty-four species were taken on traps in peach trees. Fall migrants of certain species were taken from early in September through the period of December 9 to 18. Viviparae began to move from the summer hosts several days earlier than did the male migrants. Viviparae outnumbered males about 6 to 1. Only the green peach aphid, *Myzus persicae* (Sulzer), successfully colonized and produced eggs on the peach. Feeding by other species on stone fruits was indicated by (1) the presence of numerous colonies of immature egg layers of *Amphorophora sonchi* (Oestlund) on the peach, (2) the taking of apterous egg layers of *Hyalopterus arundinis* (Fab.) and *Rhopalosiphum prunifoliae* (Fitch) on peach, (3) and the taking of apterous viviparae of five other species on other stone fruits. Egg layers of the green peach aphid must have green foliage upon which to feed to reach maturity. Early leaf-fall is an important limiting factor in the production of overwintering eggs. Summer and winter host plant records are given for 13 species taken the most frequently on traps.

LITERATURE CITED

Daniels, L. B. 1945. The peach mosaic disease. Science **101** (2613): 87–8.

Daniels, L. B. 1948. Insect vectors in relationship to spread of peach mosaic. Trans. Western Colorado Horticultural Society **1948.**

Kaloostian, G. H. and M. S. Yoemans. 1944. A sticky trap board used in scouting for pear psylla. U.S.D.A. B.E.P.Q. Publ. ET **220.**

Newton, J. H., and G. M. List. 1947. DDT to control the green peach aphis. JOUR. ECON. ENT. **39**(5): **661.**

Palmer, M. A. 1953. Aphids of the Rocky Mountain Region, pp. 1–450, 8 pls., The Thomas Say Foundation. The Entomological Society of America.

Patch, Edith M. 1938. Food-plant catalogue of the aphids of the world. Maine Agr. Expt. Station Bul. **393.**

Standardized Plant Names. 1942 (Second edition). McFarland Co., Harrisburg, Pa.

Effectiveness Against Mosquitoes of General-Purpose Repellent Mixtures for Application to Clothing[1,2]

CARROLL N. SMITH and I. H. GILBERT,[3] *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Laboratory and field experiments were continued during 1951 and 1952 at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine to develop an improved treatment for clothing to protect military personnel against mosquitoes, fleas, ticks, and mites. Previous experiments (Smith & Cole 1951, and unpublished data) demonstrated that a mixture containing equal parts of three repellents—benzyl benzoate, *N*-butylacetanilide, and 2-butyl-2-ethyl-1,3-propanediol—known as M-1960, was satisfactory for this purpose. At the present time no recommendations are made for the civilian use of M-1960, owing to insufficient toxicological data to clear the mixture for unrestricted and unsupervised use. The present study consists of tests with new mixtures against three species of mosquitoes in an effort to develop a mixture of greater general effectiveness. Tests against fleas, ticks, and mites are in progress.

MATERIALS AND METHODS.—Fifteen modifications of the standard clothing repellent mixture, M-1960, were made by replacing one or more of its ingredients with other compounds in an effort to increase its effectiveness against one or more species without reducing its effectiveness against others. The composition of the mixtures is given in table 1. Materials included in the new mixtures because of their outstanding effectiveness against one or more species were as follows: *N*-Isopropylacetanilide, *N*-propylacetanilide, and dibutyl adipate against ticks; *N*-butyl-4-cyclohexene-1,2-dicarboximide against mosquitoes; hendecenoic (undecylenic) acid against mosquitoes and fleas; and lindane against chiggers and lice. Cotton stockings were impregnated with the mixtures at dosages of 3.3 to 3.6 grams per square foot.

Table 1.—Percentage composition of repellent mixtures. (All mixtures contained 10 per cent of Tween 80.)

Mixture No. M-	Benzyl benzoate	*N*-Butylacetanilide	2-Butyl-2-ethyl-1,3-propanediol	*N*-Butyl-4-cyclohexene-1,2-dicarboximide	Hendecenoic (undecylenic) acid	*N*-Propylacetanilide	*N*-Isopropylacetanilide	Lindane	Dibutyl adipate
1960	30	30	30	—	—	—	—	—	—
2006	30	—	30	—	—	30	—	—	—
2033	30	—	30	—	—	—	30	—	—
2034	30	—	30	30	—	—	—	—	—
2035	30	—	30	—	30	—	—	—	—
2036	30	30	—	30	—	—	—	—	—
2037	30	30	—	—	30	—	—	—	—
2038	—	30	30	30	—	—	—	—	—
2039	—	30	30	—	30	—	—	—	—
2040	—	30	—	30	30	—	—	—	—
2041	18	18	18	18	18	—	—	—	—
2059	29.7	29.7	29.7	—	—	—	—	1	—
2060	30	—	30	—	—	—	—	—	30
2061	—	30	30	—	—	—	—	—	30
2065	—	—	—	29	29	29	—	3	—
2066	—	—	—	29.7	29.7	29.7	—	1	—

Tests of the treated stockings were conducted in the laboratory against *Aëdes aegypti* (L.) and *Anopheles quadrimaculatus* Say, and in the field against salt-marsh mosquitoes, principally *Aëdes taeniorhynchus* (Wied.). The tests against *quadrimaculatus* and *taeniorhynchus* were made after the stockings had been worn by laboratory personnel. The stockings were tested after each 8-hour period of wear. Tests against *aegypti* were made after various periods of aging during which the stockings were hung on lines in the laboratory.

In the laboratory tests the stockings were exposed on the arm of a subject for

[1] Presented at the meeting of the American Association of Economic Entomologists at Philadelphia, Pa., December 15–18, 1952.

[2] This work was conducted under funds allotted by the Department of the Army to the Bureau of Entomology and Plant Quarantine.

[3] The authors acknowledge the assistance of W. V. King and W. C. McDuffie in the general planning of the experiments, and of M. M. Cole, Sims R. Pratt, Nelson Smith, and other members of the staff in the testing.

Table 2.—Effectiveness of 11 repellent mixtures as clothing treatments against *Aëdes aegypti* through 19 days of aging, May 1951.

Mixture No. M-	Bites per Stocking in 8 Tests	
	Range	Average
2040	1–2	1.3
2041	1–4	2.7
2035	1–5	2.7
2034	2–9	6
2038	2–10	6
2006	3–13	7
2039	7–16	13
2033	8–26	17
2036	17–24	20
2037	9–28	20
1960	14–28	22

1 minute in a cage of 1,000 to 2,000 mosquitoes 4 to 6 days old. The same subject tested each of the stockings in succession to reduce the influence of host attractiveness in comparisons between different treatments. Tests with any stockings were discontinued when 10 or more bites were received in 1 minute.

In the field tests the stockings were exposed on the legs of subjects to natural infestations of mosquitoes showing a biting rate of 25 or more per minute on an untreated stocking. Each stocking was exposed for 5 minutes on each of three subjects to reduce the effect of differences in host attractiveness. Tests with any stocking were discontinued when at least two subjects received bites and the total number of bites for the three 5-minute exposures was 15 or more.

Tests Against *Aëdes aegypti*.—Preliminary tests against *A. aegypti* with 11 mixtures were conducted in May 1951. Four stockings were treated with each mixture, and the entire group was tested every second or third day. Eight tests were made with each stocking between the third and nineteenth days after treatment, after which the test was terminated. The relative effectiveness of a mixture was based on the total number of bites through each stocking. The results are presented in table 2.

Six of the mixtures were much more effective than M-1960, one was slightly better, and three were approximately equal. In all the best mixtures another material was substituted for *N*-butylacetanilide or benzyl benzoate. In M-2040 two outstanding mosquito repellents replaced 2-butyl-2-ethyl-1,3-propanediol and benzyl benzoate. Thus each of the six best mixtures, except M-2006, contained 54 to 60 per cent of compounds that are outstanding mosquito repellents, whereas M-1960 contains only 30 per cent of one such compound, 2-butyl-2-ethyl-1,3-propanediol. The favorable results with M-2006, which contained *N*-propylacetanilide, were somewhat unexpected, since in previous tests this compound alone was not appreciably better than *N*-butylacetanilide.

Later in 1951 additional tests were conducted with stockings treated with the same mixtures after various periods of aging. Four stockings were treated with each mixture and tested 3 to 5 times a week until 10 or more bites were received in a single exposure. The results are presented in table 3.

Table 3.—Duration of effectiveness of 11 repellent mixtures as clothing treatments against *Aëdes aegypti*, 1951.

Mixture No. M-	Days Effective	
	Range	Average
2035	37–39	37.8
2037	30–38	35.5
2041	34–36	35.3
2040	28–38	34.5
2039	28–36	33.8
1960	23–28	25.3
2034	23–29	25.0
2006	23–23	23.0
2033	20–24	21.8
2038	20–23	21.3
2036	21–21	21.0

Five mixtures—M-2035, M-2037, M-2039, M-2040, and M-2041—were more effective than M-1960. All except M-2041 contained 30 per cent of undecylenic acid. Stockings treated with these mixtures were effective 8 to 12 days longer than those treated with M-1960, and the minimum records with them equaled or exceeded the maximum with M-1960. Mixtures M-2035 and M-2041 gave 100 per cent protection for 3 weeks, as did M-2006, but all stockings treated with the last mixture failed after 23 days, whereas those treated with M-1960 were effective for 23 to 28 days. Mixture M-2034 was equal to M-1960, and both were slightly more effective than M-2033, M-2036, and M-2038.

Some of the mixtures that were better than M-1960 in these tests were less effec-

tive in tests against other species of arthropods. In general M-2040 was more satisfactory than the other mixtures, but against some species mixtures containing *N*-propylacetanilide were best, and against others lindane and dibutyl adipate were highly effective. Therefore in 1952 a series of tests was conducted with five new mixtures in which these compounds were substituted for others in the M-2040 and M-1960 formulas. The tests were conducted in the same manner as those in 1951. The results are given in table 4.

Table 4.—Duration of effectiveness of seven repellent mixtures as clothing treatments against *Aëdes aegypti*, 1952.

Mixture No. M-	Days Effective	
	Range	Average
2066	44+–44+	44+
2065	20–44+	32+
2040	10–20	13.5
1960	3–3	3
2059	2–3	2.7
2061	0–2	1.3
2060	0–0	0

Table 5.—Duration of effectiveness of 16 repellent mixtures as clothing treatments against salt-marsh mosquitoes. Three or four replications except where otherwise indicated.

Mixture No. M-	Hours of Wear Withstood			
	Range		Average	
	1 Bite	5 Bites	1 Bite	5 Bites
	Tests in 1951			
2040	24–40	56–64	32	60
1960	0–48	48–64	28	56
2038	24–56	48–56	42	54
2034	32–48	48–64	40	54
2035	0–48	48–64	20	54
2041	0–32	48–64	16	54
2033	24–32	48–56	28	52
2006	24–32	32–64	28	50
2039	8–32	40–56	18	50
2036	8–32	32–48	16	38
2037	0–32	8–56	18	36
	Tests in 1952			
1960[1]	0–8	8–48	3	30
2065	8–16	23–32	11	27
2059[2]	0–0	16–48	0	27
2066	0–24	16–32	13	24
2040	0–8	16–24	3	21
2060	0–0	0–0	0	0
2061	0–0	0–0	0	0

[1] Nine replications.
[2] Six replications.

The mosquitoes used for the tests in 1952 were unusually avid. M-1960 was effective for only 3 days, and M-2040 for 10 to 20 days, whereas the new mixtures containing *N*-propylacetanilide and lindane remained effective more than 30 days.

TESTS AGAINST SALT-MARSH MOSQUITOES.—In the late summer and fall of 1951 and 1952 the new mixtures were compared with M-1960 in the field against salt-marsh mosquitoes. Three or four stockings treated with each material were tested concurrently until on an average five bites were received on three hosts. Each stocking was worn 8 hours before each test, and the effectiveness was based on the hours of wear withstood. Results of the tests are presented in table 5.

In the 1951 series M-2040 was slightly superior to M-1960 in resistance to the first and fifth bite, and M-2034 and M-2038 were superior with reference to the first bite only. These three mixtures contained *N*-butyl-4-cyclohexene-1,2-dicarboximide and either 2-butyl-2-ethyl-1,3-propanediol or undecylenic acid.

Mixtures M-2006 and M-2033 were equal to M-1960 with respect to the first bite, and only slightly inferior to five bites. These substituted *N*-propylacetanilide and *N*-isopropylacetanilide for *N*-butylacetanilide, The other five mixtures were decidedly less resistant than M-1960 to the first bite, and two, M-2036 and M-2037, were also decidedly less resistant to five bites. In the last two mixtures another compound was substituted for 2-butyl-2-ethyl-1,3-propanediol.

In the 1952 series the mixtures containing *N*-propylacetanilide and lindane, M-2065 and M-2066, were more resistant than M-1960 to the first bite, but slightly less resistant to the fifth bite. The other mixtures were less effective than M-1960 in one or both respects.

TESTS AGAINST *Anopheles quadrimaculatus*.—During the spring of 1952 several mixtures were compared with M-1960 against *Anopheles quadrimaculatus* in the laboratory. Three stockings treated with each material were tested concurrently until more than 10 bites were received in a 2-minute exposure. Each stocking was worn 8 hours before each test and effectiveness was based on the hours of wear withstood. Results of the tests are presented in table 6.

Table 6.—Duration of effectiveness of 11 repellent mixtures as clothing treatments against *Anopheles quadrimaculatus*, 1952.

Mixture No. M-	Hours of Wear Withstood	
	Range	Average
1960	16–24	21.3
2006	16–24	21.3
2033	16–24	21.3
2037	8–24	16.0
2038	0–24	13.3
2040	8–16	13.3
2041	0–24	13.3
2035	0–16	10.7
2036	0–16	10.7
2039	8–16	10.7
2034	0–8	5.3

Only two of the new mixtures, M-2006 and M-2033, were equal to M-1960 in effectiveness. They contained *N*-propylacetanilide or *N*-isopropylacetanilide instead of *N*-butylacetanilide.

SUMMARY.—Fifteen modifications of the standard clothing repellent mixture, M-1960, which contains benzyl benzoate, *N*-butylacetanilide, and 2-butyl-2-ethyl-1,3-propanediol, made by replacing one or more of its ingredients with other compounds, were tested against three species of mosquitoes in 1951 and 1952. All mixtures that contained undecylenic (hendecenoic) acid and some that contained *N*-butyl-4-cyclohexene-1,2-dicarboximide were more effective than the standard against *Aëdes aegypti* (L.), but all were less effective against *Anopheles quadrimaculatus* Say. Some without 2-butyl-2-ethyl-1,3-propanediol were less effective than the standard against salt-marsh mosquitoes. Replacement of *N*-butylacetanilide with *N*-propylacetanilide or *N*-isopropylacetanilide caused no consistent changes in effectiveness.

LITERATURE CITED

Smith, C. N., and M. M. Cole. 1951. Mosquito repellents for application to clothing. Jour. Natl. Malaria Soc. 10(3): 206–12.

Field Compatibility of Aramite and Sulfur in California[1]

F. A. GUNTHER, H. T. REYNOLDS, and L. R. JEPPSON,[2] *University of California Citrus Experiment Station, Riverside, California*

There have been many conflicting reports about the field compatibility of sulfur-containing Aramite[3] preparations, both with dust and wettable powder formulations and with Aramite preceding or following sulfur applications. No reports of supposed incompatibility have been published, but numerous observations of compatibility may be found in the available literature. The present investigation was undertaken to resolve this problem on cotton, Lima bean, and lemon foliage by evaluating the persistence of Aramite residues, including both dusts and wettable powders, with and without sulfur.

MATERIALS AND METHODS.—Four formulations were evaluated: Aramite 3 per cent dust (with and without sulfur) on cotton and bean plants, and Aramite 15 per cent wettable powder (with and without sulfur) on lemon trees. These formulations were prepared in the usual manner in commercial-type equipment.

The cotton test was conducted on Alcala 442 variety cotton in the Coachella Valley of southern California. Dust applications were made on cotton about 3 feet tall by a small row-crop power duster operated with two nozzles per cotton row. A single application was made on August 26, 1952, to plots four rows wide and 100 feet long. Each treatment was replicated four times. In this test 3 per cent Aramite dust was applied at the rate of 31 pounds per acre, and 3 per cent Aramite plus 55 per cent sulfur dust was applied at the rate of 25 pounds per acre. Maximum temperatures during the period of this test ranged from 97° to 116° F., and the average maximum was 111° F. Minimum temperatures ranged from 65° to 88° F., and the average minimum was

PAID PAPER.

[1] Paper No. 764, University of California Citrus Experiment Station, Riverside, California.

[2] Grateful acknowledgment is made to Mr. James H. Barkley of these laboratories, and to Mr. Paul R. Wood of the Naugatuck Chemical Division of the U. S. Rubber Company, for performing the analytical determinations.

[3] Product containing 2-(*p-tert.*-butylphenoxy)isopropyl-2-chloroethyl sulfite.

80° F. Leaf samples were collected immediately after treatment and at intervals of 1, 4, 7, and 16 days thereafter. Samples of mature leaves were taken from the upper third of the plant and from the same inside row on each sampling date. One leaf was taken from the northern and one from the southern exposure of each plant selected. Forty leaves were collected from each replicate for a total of 160 leaves per treatment.

The test on Fordhook Lima beans was conducted on University of California property at Riverside. Dust applications were made on nearly mature beans by a rotary hand duster operated with two nozzles per bean row. A single application was made on September 11 to plots three rows wide and 40 feet long. Each treatment was replicated three times. In this test 3 per cent Aramite dust was applied at the rate of 36 pounds per acre, and 3 per cent Aramite plus 55 per cent sulfur was applied at the rate of 30 pounds per acre. In addition, on a third set of plots, 3 per cent Aramite dust was applied at a rate of 36 pounds per acre over a fresh application of 98 per cent sulfur, which had been used at the rate of 45 pounds per acre. Maximum temperatures during the period of this test ranged from 78° to 105° F., and the average maximum was 96° F. Minimum temperatures ranged from 45° to 58° F., and the average minimum was 52° F. Samples of mature leaves were collected immediately after treatments and at intervals of 1, 3, and 6 days thereafter. These samples, consisting of entire trifoliate leaves, were taken from the center row, only, of each plot. Thirty-leaf samples were collected from each replicate for a total of 90 leaves per treatment.

On mature lemon trees, the 15 per cent Aramite wettable powder formulation applied at the rate of 2 pounds per 100 gallons of aqueous spray was compared with a similar application of 15 per cent

Table 1.—Ranges and averages of persisting Aramite residues as micrograms of Aramite per square centimeter of foliage.

Formulation	Days After Application				
	0	1	4	7	16
On Cotton Foliage (4 Field Replicates)					
Aramite 3% dust	1.62–2.55 Av. 2.00	0.56–0.85 Av. 0.72	0.15–0.64 Av. 0.43	0.03–0.05 Av. 0.04	0.00 Av. 0.00
Aramite 3% dust containing 55% sulfur	0.39–0.91 Av. 0.60	0.35–0.71 Av. 0.50	0.04–0.09 Av. 0.07	0.02–0.05 Av. 0.03	0.00 Av. 0.00
Check plot (Av.)	0.00	0.00	0.00	0.00	0.00
On Lima Bean Foliage (3 Field Replicates)					
Aramite 3% dust	0.52–1.01 Av. 0.69	0.68–0.97 Av. 0.82	0.19–0.27 Av. 0.23	0.05–0.13 Av. 0.08	
Aramite 3% dust containing 55% sulfur	1.07–1.23 Av. 1.15	0.57–0.83 Av. 0.68	0.19–0.41 Av. 0.29	0.06–0.27 Av. 0.15	
Aramite 3% dust applied over previously applied sulfur	0.35–1.43 Av. 0.73	0.62–1.07 Av. 0.75	0.13–0.35 Av. 0.28	0.11–0.32 Av. 0.18	
Check plot (Av.)	0.00	0.00	0.00	0.00	
On Lemon Foliage (3 Field Replicates)					
Aramite 15% WP (spray)	2.73–3.93 Av. 3.32	2.35–3.61 Av. 3.09	1.30–2.46 Av. 2.04	1.97–2.76 Av. 2.33	0.67–1.24 Av. 0.94
Aramite 15% WP containing 50% sulfur (spray)	0.76–2.11 Av. 1.64	1.52–1.73 Av. 1.66	0.93–2.00 Av. 1.37	0.70–1.06 Av. 0.85	0.24–0.30 Av. 0.28
Check plot (Av.)	0.00	0.00	0.00	0.00	0.00

Aramite plus 50 per cent sulfur. Approximately 1,000 gallons of final spray were required per acre for the 90 trees involved. Each treatment was replicated three times. Applications were made as conventional sprays, using a high-pressure reciprocating pump and manually operated spray guns. Maximum temperatures during the period of this test ranged from 77° to 99° F., and the average maximum was 88° F. Minimum temperatures ranged from 44° to 60° F., and the average minimum was 50° F. Leaf samples were clipped and permitted to drop into widemouthed fruit jars without handling the leaf blades. Twenty mature leaves (5 per quadrant) were taken from each of six sample trees per plot, and the resulting 120 leaves were processed as a unit, with a total of 360 leaves per treatment. Samples were collected as soon as the spray application was dry and at intervals of 1, 3, 7 , and 17 days thereafter.

All leaf samples were weighed, stripped, then measured photoelectrically (Gunther 1948) for surface areas on the day the samples were collected. Technical grade benzene was used as the stripping solvent, at the rate of 200 ml. for each cotton sample and 400 ml. for each bean and lemon sample; stripping time was 30 minutes, in standard equipment (Gunther & Blinn 1950). After being filtered through Sharkskin filter paper, the leaf extracts were evaporatively concentrated and analyzed for Aramite content in a four-unit apparatus, according to the colorimetric procedure of Gunther *et al.* (1951).

It is important to note that the diethylene glycol involved in this procedure must be redistilled and fractionated at atmospheric pressure, not under reduced pressure.

RESULTS.—Ranges and average values of persisting Aramite residues found on the three types of foliage at intervals after application are shown in table 1. When these data are plotted as log residue value versus time interval, the straight lines typical of first-order reactions are obtained. The rate of disappearance (loss of identity to the colorimetric method utilized) of the Aramite in all the formulations utilized, and on the three types of foliage, is directly proportional to the *concentration* of the Aramite in each situation; thus, it takes twice as long for three-fourths of the Aramite to disappear as it takes for half of it to disappear.

Table 2.—Half-life values for residues of Aramite alone and in the presence of sulfur on cotton, Lima bean, and lemon foliage (obtained graphically).

FOLIAGE	MATERIAL	RESIDUE HALF-LIFE (DAYS)
Cotton	Aramite	1.3
	Aramite+S	1.8
Lima bean	Aramite	2.2
	Aramite+S	1.8
	Aramite over S	2.5
Lemon	Aramite	9.2
	Aramite+S	6.3

DISCUSSION.—From these data and from their first-order relationships it is clear that sulfur causes no acceleration in the rate of disappearance of Aramite.

Half-life values (time required for given deposit values to decrease by one half) for these persisting Aramite residues are shown in table 2. These values may be obtained from the aforementioned graphical representations or from the equation $k=\frac{2.303}{t}\log\frac{a}{a-x}$, where a is the initial concentration, x is the amount reacting in time t, $a-x$ is the concentration remaining after time t, and k is the specific reaction rate constant. The rate of disappearance or loss for an organic insecticide residue may conveniently be expressed or described by means of this half-life (Gunther, manuscript in preparation). It has been well established that the uncomplicated persistence curves for deposits of the solid organic insecticides represent first-order reactions (cf. Decker *et al.* 1952). Because this loss is exponential in nature, the half-life has a definite value irrespective of the amount of material originally deposited. Presumably, the half-life represents a characteristic property of each insecticide on a given substrate, and therefore affords an excellent means of isolating the effects of accessory substances upon the persistence of that insecticide. Thus, the half-life values in table 2 clearly demonstrate that sulfur does not affect the longevity of Aramite residues under field conditions.

An outstanding feature of this table is the length of the half-life of Aramite on lemon foliage as contrasted with that on

cotton or bean foliage. This longer half-life may be attributed to one or more of several imponderables. For example, the lemon grove used in this test was located in the coastal area, where lower temperatures and higher humidities prevailed; also, it is generally recognized that spray deposits are less subject to mechanical losses than are most dust deposits. However, long residue persistence with other insecticides and acaricides has been noted previously on citrus; this is believed to be the result of rapid solution of the material into the thick layer of surface waxes characteristic of citrus fruit and foliage, with a resultant decrease in rate of residue loss after the first few hours.

The initial deposit of Aramite on cotton foliage from an application of Aramite-sulfur dust was considerably smaller than that obtained from a dust application of Aramite alone. Similar results were obtained with wettable powder sprays on lemon foliage. It is believed that this was the result of poor Aramite-sulfur formulations, and may indicate an inherent difficulty in combining these materials. These limited studies do not establish the real nature of this problem, but formulators of Aramite-sulfur mixtures should be aware of this possibility.

SUMMARY.—Studies of the quantitative persistence of Aramite and of Aramite-sulfur residues on cotton, Lima bean, and lemon foliage demonstrate the field compatibility of Aramite and sulfur. The presence of sulfur in the formulations apparently does not affect the half-life values (time required for given deposit values to decrease by one half) of the resulting residues. Aramite spray residues on lemon foliage persisted much longer than did dust residues on cotton and bean foliage.

The concept of half-life values for evaluating persistence of insecticide residues is discussed. Half-life values are independent of initial deposit and therefore warrant consideration in comparative longevity studies such as the present one.

LITERATURE CITED

Decker, G. C., C. J. Weinman, and J. M. Bann. 1952. Practical factors in persistence. Deposits and residues. Advn. in Chem. Ser. (In press.)

Gunther, F. A. 1948. Sample manipulation and apparatus useful in estimating surface and penetration residues of DDT in studies with leaves and fruits. Hilgardia **18**(6): 297–316.

Gunther, F. A., and R. C. Blinn. 1950. Mass-production techniques for estimation of parathion residues. Advn. in Chem. Ser. **1**: 72–87.

Gunther, F. A., R. C. Blinn, M. J. Kolbezen, J. H. Barkley, W. D. Harris, and H. S. Simon. 1951. Microestimation of 2-(*p-tert*-butylphenoxy) isopropyl-2-chloroethyl sulfite residues. Analyt. Chem. **23**: 1835–42.

SCIENTIFIC NOTES

Maggots Attacking Michigan Onions[1]

LELAND G. MERRILL, JR. and RAY HUTSON,
Michigan Agricultural Experiment Station, East Lansing

Maggots attacking onions greatly decrease yields of Michigan grown onions. Although damage is consistent neither from year to year nor from field to field, the over-all annual loss warrants serious study. Because previous unpublished Michigan work on onions, a study of the flies involved was carried out from 1949 to 1952. The obviously different habits of various species could account for variations in degree of infestation and in the failure of control practices.

Rearing adults from maggot-infested onions was the general method followed. In addition, supplementary collections were made by netting and trapping adults in onion fields. The data are the results of more than 100 individual collections in nine counties, involving more than 5000 specimens.

Table 1.—Diptera associated with Michigan onion growing.

Larvae Taken in Growing Onions	Adults Trapped[2] and Netted
Muscidae	Muscidae
Hylemya antiqua (Mg.)[1]	*Graphomya maculata* (Scop.)
Hylemya cilicrura (Rond.)	*Helina rufitibia* (Stein.)
Hylemya trichodactyla (Rond.)	*Helina troene* (Wlk.)
Muscina assimilis (Fall.)[1]	*Hylemya brassicae* (Bouche)
Muscina stabulans (Fall.)[1]	*Limnophora arcuata* Stein.
Fannia canicularis (L.)[1]	*Phaonia* sp.
Sphaeroceridae (Borboridae)	Scopeumatidae
Leptocera fontinalis (Fall.)	*Scopeuma furcatum* (Say)
Chloropidae	Larvaevoridae
Elachiptera costata (Lw.)	*Tachinomyia* sp.
Oscinella carbonaria (Lw.)	Sarcophagidae
Oscinella coxendix (Fitch)	*Sarcophaga bullata* Park
Drosophilidae	*Sarcophaga cimbicis* Ins.
Drosophila busckii Coq.[1]	*Sarcophaga latisterna* Park
Otitidae (Ortalidae)	*Sarcophaga lherminieri* R.D.
Chaetopsis fulvifrons (Macq.)	*Sarcophaga ohioensis* Hall
Chaetopsis massyla (Wlk.)	Calliphoridae
Euxesta notata (Wied.)[1]	*Bufolucilia silvarum* (Mg.)
Tritoxa flexa (Wied.)[1]	*Calliphora livida* (Hall)
Syrphidae	*Phormia regina* (Mg.)
Eumerus strigatus (Fall.)[1]	Syrphidae
Eumerus tuberculatus (Rond.)[1]	*Allograpta obliqua* (Say)
Syritta pipiens (L.)[1]	*Metasyrphus wiedemanni* (Johnson)
Scatopsidae	*Syrphus ribesii vittifrons* Shannon
Scatopse fuscipes (Mg.)[1]	Dolichopodidae
Fungivoridae (Mycetophilidae)	*Dolichopus finitus* (Wlk.)
Bradysia sp.[1]	Bibionidae
Larvae Taken in Cull Piles Only	*Bibio albipennis* Say
Muscidae	
Fannia scalaris (Fall.)	
Hydrotaea houghi (Fall.)	
Drosophilidae	
Drosophila immigrans Sturt.	
Syrphidae	
Tropidia quadrata (Say)	
Stratiomyidae	
Actina viridis (Say)	
Stratiomys meigenii Wied.	
Scatopsidae	
Scatopse notata (L.)	
Fungivoridae	
Leia bivittata Say	
Leia oblectabilis (Lw.)	
Sylvicolidae (Anisopidae)	
Sylvicola alternata (Say)	

[1] Larvae also collected in cull piles.
[2] No larvae found.

casionally noted dipterous species other than *Hylemya antiqua*, the onion maggot, infesting

RESULTS.—Table 1 indicates that 52 dipterous species were collected in onion fields or nearby cull piles. Of these 52 species 20 were taken from the growing onions. Of these 20 species, only seven were important in damaging onion plantings as seen in table 2.

Hylemya antiqua was the most numerous species. However, in May and June, nearly a fifth of the

[1] Sincere thanks are extended to Dr. C. F. W. Muesebeck of the Division of Insect Identification, U.S.D.A., Washington, D.C. without whose aid this problem could not have been undertaken. Special credit is due to C. W. Sabrosky, Alan Stone, W. W. Wirth, and R. H. Foote who determined the majority of specimens.

Approved by the Director, as Journal Article 1484, Michigan Agricultural Experiment Station.

Table 2.—Flies reared from maggots infesting onions in the field.

SPECIES	PER CENT EACH SPECIES PER COLLECTION			PER CENT OF ALL INFESTATION
	May & June	July	August	
Hylemya antiqua	76.7	74.8	49.4	66.9
Hylemya cilicrura	18.4	5.5	—	7.9
Hylemya other	—	0.1	—	0.03
Eumerus {*strigatus* / *tuberculatus* / spp.}	0.1	4.7	32.8	12.5
Muscina stabulans	4.4	4.9	7.3	5.5
Muscina assimilis	0.3	3.5	3.4	2.7
Euxesta notata	—	1.9	6.2	2.7
Scatopse fuscipes	—	2.0	—	0.7
Chaetopsis fulvifrons	—	0.6	—	0.2
Bradysia sp.	—	0.6	—	0.2
Chaetopsis massyla	—	0.2	0.3	0.2
Drosophila busckii	—	—	0.4	0.1
Elachiptera costata	—	0.4	—	0.1
Fannia canicularis	—	0.2	—	0.07
Tritoxa flexa	—	0.2	—	0.07
Oscinella cozendix	—	0.1	—	0.03
All others	0.1	0.3	0.2	0.1

adults reared were *H. cilicrura*, the seed corn maggot. In fields where both *H. antiqua* and *H. cilicrura* were present, *H. cilicrura* was in its greatest proportion on the earlier collection dates. Also, gravid *H. cilicrura* females were collected earlier in the season than were those of *H. antiqua*. In 1952 *H. cilicrura* was found on April 22 and *H. antiqua* on May 9. According to Ristich & Schwardt (1949) the seed corn maggot attacks germinating plants before emergence. The onion maggot's habit is to deposit eggs on or near plants which have already emerged with the larger plants receiving more attention. If the seed corn maggot were the predominant species in a field, as has been shown clearly to be the case (Merrill 1951) then spray or dust treatments to control the damage might better be applied soon after planting, rather than when the onion plants have completely emerged, or possibly a seed treatment would be indicated. After June few seed corn maggots were found although adults have been taken in the fields.

During July and August, the lesser bulb flies, *Eumerus strigatus* and *E. tuberculatus*, widely known as general scavengers, occurred as maggots in onion bulbs. Studies of these two very similar species indicated that the spring generation of these flies begins to emerge in mid-May and that this generation of flies does not lay eggs on the tiny seedling onions but is attracted to volunteer bulbs and cull piles. The second generation of these flies begins to emerge in late June and lays eggs on the growing onions which by this time have developed bulbs. Opinions vary (Doucette 1941; Seamans, 1930) as to whether these pests will attack sound growing plants and certainly most lesser bulb fly maggots came from fields having previous *Hylemya antiqua* and or *H. cilicrura* infestation. However, on one occasion, when the initial infestation occurred in July, *E. tuberculatus* was definitely the primary offender. The possibility does exist here that slight smutting of the onions by the organism *Urocystis cepulae* Frost, could have occurred although the onions collected were definitely not noticeably infested with smut. Lesser bulb fly larvae were found overwintering abundantly in muck soil fields (at a depth of 1 to 2 inches) following heavy maggot infestations.

The control of lesser bulb fly usually depends upon good control of either or both *Hylemya cilicrura* and *H. antiqua*. If growers experience primary lesser bulb fly infestation in July and August, the possibility of a combination onion thrips-lesser bulb fly-mildew control program suggests itself, in which application of chemicals would coincide with activity of the second brood fly activity, in the field.

The false stable fly, *Muscina stabulans* and a closely related species *M. assimilis* were found to be active throughout the season. These maggots were found in increasing numbers during each year and were never found to be a primary invader. The larvae of both species have been regarded as filth infesting and Ristich (1950) regards *M. assimilis* larvae as carnivorous and *M. stabulans* larvae as semi-carnivorous.

The very common otitid fly, *Euxesta notata* was taken in some numbers later in the season but was found to be a secondary invader and in relatively small numbers in growing onions.

Table 3.—Flies reared from cull pile onions (New) (1949–1952).

SPECIES	AVERAGE PER CENT PER COLLECTION
Hylemya antiqua	42.6
Muscina assimilis	12.5
Muscina stabulans	8.4
Euxesta notata	7.2
Eumerus {*strigatus* / *tuberculatus* / spp.}	7.0
Scatopse fuscipes	4.0
Fannia canicularis	3.5
Scatopse notata	2.6
Sylvicola alternata	2.2
Syritta pipiens	1.6
Tritoxa flexa	1.5
Stratiomys meigenii	1.4
Drosophila busckii	1.1
Bradysia sp.	1.0
Leia bivittata	0.9
Leia oblectabilis	0.8
Actina viridis	0.6
Hydrotaea houghi	0.4
Drosophila immigrans	0.3
Tropidia quadrata	0.2
Fannia scalaris	0.1
Fannia sp.	0.1

Studies of cull piles revealed that the predominant species in new cull piles was *Hylemya antiqua* which, however, was taken only in new cull piles in the fall or early spring of the year following. The implication is that *H. antiqua* does not breed in old cull piles. As has already been reported, to reduce the number of this insect by destruction of infested cull onions, the onions should be disposed of preferably at harvest or before the next spring. Maggots may emerge from the infested onions during the fall and pupate within the soil, hence destruction of culls after an appreciable time beyond harvest would not affect the soil-inhabiting pupae.

After the first spring, old cull piles were not infested with onion maggot, but a great variety of scavengers, predators and incidental pests were found. The syrphid fly, *Syritta pipiens* was taken in great numbers. In a few of these older piles *S. pipiens* was the only larger fly species, the majority of the rest being small fungivorids, and drosophilids and

scatopsids. *S. pipiens* was not a major pest of growing onions although it was taken from one heavily infested field in August. Since some of the secondary field pests such as *Euxesta notata* and the *Eumerus* species are found in cull piles, the destruction of culls would aid in the reduction of population of these insects.

SUMMARY AND CONCLUSIONS.—A study of maggots infesting Michigan grown onions revealed the following facts:

1. Fifty-two species of flies were taken in onion fields. Only 20 of these were taken as maggots in growing onions and of these 20 just six or seven were of any importance. The multiplicity of species present in a field may confuse growers unfamiliar with technical identification.

2. *Hylemya antiqua*, the onion maggot caused most of the damage to Michigan grown onions.

3. *Hylemya cilicrura* caused a significant part of all maggot damage to onions during May and June. The earlier collections had a higher proportion of *H. cilicrura* than later collections. The attack of germinating onions by this pest may alter the timing of recommended spray and dusting control measures.

4. Maggots of lesser bulb flies, *Eumerus strigatus* and *E. tuberculatus* were collected in great numbers from growing onions in late July and August. Although these species are not usually primary invaders of healthy bulbs, at least one case of primary infestation of set onions was observed.

5. *Hylemya antiqua*, although found in fresh cull piles, was not taken there after the emergence of the first generation of flies in the spring. This re-emphasizes the necessity of immediate destruction of cull onions after harvest to prevent the development of maggots.

6. The Diptera reared from old onion cull piles were scavenger or predator species.

LITERATURE CITED

Doucette, C. F. 1941. Control of Insects and Mites Attacking Narcissus Bulbs. USDA Farmers Bulletion **1890**: 10–14.

Merrill, L. G. 1951. Diptera Reared from Michigan Onions Growing from Seed. JOUR. ECON. ENT. **44**(6): 1015.

Ristich, S. S. and H. H. Schwardt, 1949. Biology and Control of the Seed Corn Maggot on Beans in New York. JOUR. ECON. ENT. **42**(1): 77–80.

Ristich, S. S. 1950. Biology of the Seed Corn Maggot *Hylemyia cilicrura* (Rond.) and Preliminary Studies for Its Control. Ph.D. Thesis Cornell Univ., Ithaca, N. Y.

Seamans, H. L. 1930. 61st Annual Report of Ont. Ent. Soc.: 29.

Some Natural Enemies of Horse Flies in New York

H. TASHIRO[1] and H. H. SCHWARDT, *Cornell University, Ithaca, New York*

While studying the general biology of Tabanide in New York during the summer of 1949, four parasites of this family were recovered. Three were egg parasites—one from *Chrysops* eggs and two from *Tabanus* eggs. A single specimen of a larval parasite was reared to an adult. Logothetis (1947)[2] reported finding many parasitized *Tabanus* egg masses, and *Telenomus tabanivorus* (Ashm.) (Scelionidae) was one of the parasites. His is the first report of this species in New York.

Chrysops EGG PARASITES.—Many *Chrysops* egg masses deposited on cattail (*Typha*) leaves bordering a small pond were found heavily parasitized. These egg masses were typical of most *Chrysops* in being single tiered. They were all identical in appearance and presumably eggs of the same species. Many parasites were reared to adults by taking a small section of the leaf bearing an egg mass to the laboratory and keeping it in a shell vial until emergence. The parasites were all determined as *Trichogramma semblidis* (Aur.) (Trichogrammatidae) by A. B. Gahan of the U. S. National Museum.

Eggs which had been parasitized could be determined by the appearance of the empty chorion. Generally, they were along the periphery of an egg mass. An egg from which a parasite emerged remained black and opaque and had a circular emergence hole in the outer exposed surface. Only one parasite developed and emerged from each egg. An egg from which a *Chrysops* larva hatched became translucent and larval emergence was through a longitudinal slit in the chorion.

To determine the degree of parasitism by this parasite, all the egg masses which could be found at this pond were collected throughout the summer and examined. Seventy-three egg masses were collected and 57 were parasitized with a majority of the eggs

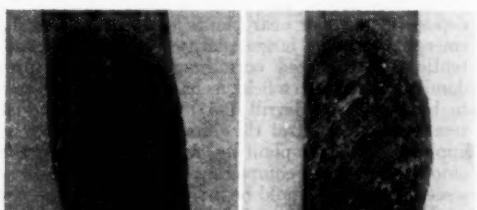


FIG. 1.—Egg mass of *Tabanus atratus* (a) before emergence of parasites or hatching of tabanid larvae and (b) after emergence and hatching. Ithaca, N. Y. 1949.

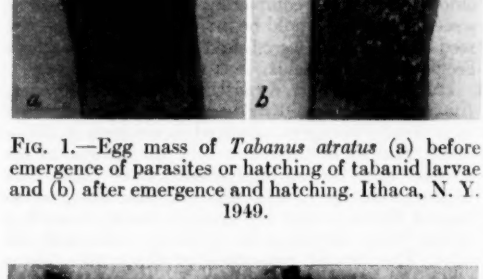


FIG. 2.—*Telenomus tabanivorus* adults and single *Tabanus atratus* egg. A single male parasite in upper center and distinguished from females by shorter abdomen and lack of ovipositor. Ithaca, N. Y. 1949.

[1] At present with the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

[2] The Biology of some Tabanidae of New York. Ph.D. Thesis, Cornell University. 90 pp.

destroyed. Only 16 masses were entirely free from parasitism.

Tabanus EGG PARASITES.—Two species of egg parasites were recovered from this genus. An egg mass of *Tabanus lasiophthalmus* Macquart which was collected at the Allegany State Park by L. L. Pechuman, and another egg mass of the same species collected near Ithaca were parasitized by *Telenomus goniopis* Cwfd. These were determined by C. F. W. Muesebeck of the U. S. National Museum. Schwardt (1936) reported this species as an egg parasite of *Goniops chrysocoma* Osten Sacken in Arkansas.

Several egg masses of the black horsefly, *Tabanus atratus* Fabricius, collected on cattails at the edge of the same pond mentioned above were found parasitized by *Telenomus tabanivorus*. These were also determined by C. F. W. Muesebeck.

Five days after collecting one *T. atratus* egg mass many larvae hatched from the eggs in the interior of the egg mass and escaped through an opening in the apex of the mass as shown in figure 1 (b). The surface eggs still contained developing individuals which were definitely not tabanid larvae. Examination the following day indicated that they were pupae of the parasites. All the parasites emerged on the sixth and seventh day following the hatching of the tabanid larvae. Each parasitized egg produced a single adult. In actual count this egg mass produced 430 tabanid larvae and 371 adult parasites. Counting the dozen or more eggs destroyed in preliminary examinations this egg mass totaled more than 810 eggs, which is the record number of eggs for a single mass.

Three other egg masses of *T. atratus* from the same locality showed approximately the same degree of parasitism by the same parasite. Determination of the degree of parasitism was also possible in these eggs since the parasite emerged from a circular opening in the chorion whereas the tabanid larva emerged through a longitudinal slit.

Tabanus LARVAL PARASITE.—One of the *Tabanus* larvae being reared was found dead and showed a peculiar swelling in the thoracic region which appeared to be caused by a large brown puparium inside. The disintegration of the host cadaver revealed the suspected puparium and 17 days later a male tachinid emerged. It was determined by H. J. Reinhart of Texas A. and M. College as *Vibrissotheresia pechumani* n. sp. According to him, this is the second record of this species, the first being a male, the holotype collected by L. L. Pechuman at Brewster, New York.[1] The parasitized larva was collected from the muddy banks of a small creek near Ithaca in association with larvae of *Chrysops wiedemanii* Krober and *Tabanus reinwardtii* Wiedemann, and was probably a larva of this latter species.

SUMMARY.—*Chrysops* egg masses were found heavily parasitized by *Trichogramma semblidis*. *Tabanus* egg masses were found parasitized by two species; *T. lasiopthalmus* eggs by *Telenomus goniopis* and *T. atratus* eggs by *Telenomus tabanivorus*. An egg which has been parasitized by any of the three egg parasites could be distinguished from a parasite-free egg by the circular emergence hole made by the adult parasite or the longitudinal slit made by the hatching larva. One *Tabanus* larva was found parasitized by a tachinid, *Vibrissotheresia pechumani*.

LITERATURE CITED

Schwardt, H. H. 1936. Horseflies of Arkansas. Arkansas Agr. Expt. Sta. Bul. 332: 1–66.

[1] Brooklyn Entomological Society Bul. 38: 86. 1943.

Notes on the Biology of *Tabanus giganteus*

H. TASHIRO[1] and H. H. SCHWARDT,[2] *Cornell University, Ithaca, New York*

While studying the biology of the major species of horseflies in Central New York during the summers of 1948 and 1949, habits of *Tabanus giganteus* Degeer adults were noted and several individuals were reared from egg to adult. This is one of the largest of Nearctic tabanids surpassed in size only by *Tabanus americanus* Forster. Females of *T. giganteus* measure 22 to 25 mm. in length and have a wing spread of 45 to 50 mm. They are uniformly dark brown in color with no marked sexual dimorphism other than the usual holoptic-dichoptic condition of the eyes. Practically nothing has been known about the biology of this species.

During the 2 years of investigation, 13 females were collected and several others were observed. This seems to be even a later species than the autumn horsefly, *Tabanus sulcifrons* Macquart, since during both years they were taken after the latter had been on the wing for at least two weeks. They were seen throughout August and the first week in September. In contrast to *T. atratus* Fabr. females, which fly around an animal for several minutes before alighting for a blood meal, this species flies directly to an animal, comes to rest, and immediately begins feeding. In this respect their habits are similar to those of *T. sulcifrons*. Only four were collected on an animal and in every incidence attacked the cow on her back. Other individuals were taken as they flew into a moving or standing vehicle during the day. Others flew into buildings through open windows. A single fly possibly attracted to lights flew into a room during the night. A few were seen during cool damp mornings, especially during September, resting on the warm hood of a car.

CHARACTERISTICS OF EGG MASS.—One egg mass, which contained between 300 and 400 eggs, was obtained from an engorged female held in captivity. It was three-tiered and in the shape characteristic of *Tabanus* egg masses, but was unusual in color, being bright orange-yellow. Each egg was yellow with an orange band about a third of the way from each end which gradually faded to yellow toward the middle of the egg. All other known tabanid eggs are uniformly cream, gray, brown, or black in color depending on the species. There is every reason to believe that the unusual color of the eggs is typical of this species. Egg masses of several species have been obtained both in the field and in the laboratory from captive flies. In all cases the appearance of egg masses as well as individual eggs were identical for a particular species whether obtained in the field or in the laboratory.

CHARACTERISTICS OF LARVAE.—*Tabanus giganteus* larvae like *T. sulcifrons* are uniformly cream colored. They are so much alike in color and size that their separation is possible only by characteristics found on the anal segment and visible with slight magnification. In *T. giganteus* larvae the posterior ring of the anal segment is not quite as dark nor as distinct as in *T. sulcifrons*. The pubescent arc extending from the anus to the lateral area of the posterior ring as well as the three anterior

[1] At present with the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

[2] Authors are grateful to Mr. Clement Dasch for his assistance in rearing work.

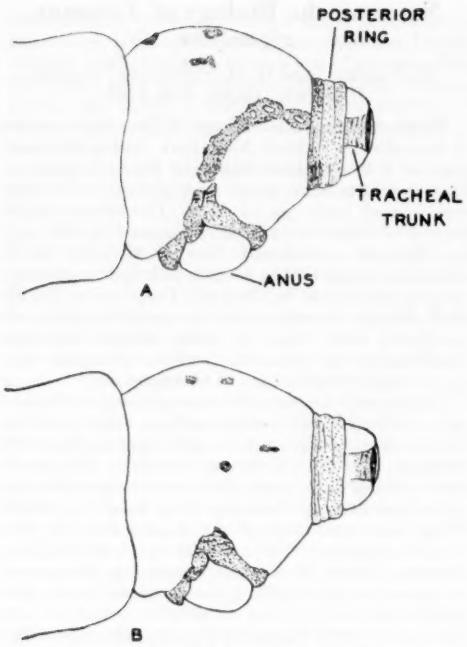


FIG. 1.—Lateral views of anal segment, larvae of *Tabanus sulcifrons* (A) and *T. giganteus* (B).

dorso-lateral pubescent spots arranged in a triangle and present on *T. sulcifrons* larvae are not present on *T. giganteus* larvae. The tracheal trunk in the anal segment of *T. giganteus* larvae is not so distinct as in *T. sulcifrons*.

Full grown larvae vary in length from 16 to 30 mm. with a mean of 20 mm. The length of living larvae is difficult to determine because of their telescoping habit. Preserved and fully relaxed specimens measure 45 to 50 mm. in length.

REARING.—The only fly which was seen on an animal in 1948 was allowed to feed to repletion. She was captured on September 3 while feeding and deposited her egg mass on September 10 on the underside of the cheese-cloth cage. Hatching occurred 10 and 11 days later. Larvae were kept in one-third pint jelly glasses containing saturated sand and fed small segments of earthworms. They became very cannabalistic after attaining a length of 3 to 4 mm. During the last week in October they ranged in length from 3 to 6 mm. and there was no indication that they would stop feeding. Many were separated one to a glass and placed in a cool cellar for hibernation, and many of the smaller ones were placed in hibernation with three larvae per glass. In nearly all cases in which three were placed in a container together, only one was left when taken out of hibernation the following April.

By the following fall larvae ranged in size from 10 to 30 mm. Many went into hibernation the second winter as grown larvae. Of the 17 adults which emerged during the summer of 1950, only one individual had a larval molt after the second winter's hibernation. Adult emergence occurred during July–September 1950. Their individual rearing data are summarized in table 1.

The larval period varied from 22 to 24 months and the pupal period varied from 16 to 24 days. Ten males and seven females emerged; earlier emergence being predominantly males with females emerging later in the season.

Table 1.—Life history data for *Tabanus giganteus* from egg mass deposited in laboratory. Eggs hatched September 20, 21, 1948. Ithaca, New York.

No. Molts	Date Pupated	Date Emerged	Larval Period Months	Pupal Period Days	Sex
7	6/26	7/14	22	18	M
6	6/28	7/17	22	19	M
7	7/3	7/19	22	16	F
5	7/3	7/19	22	16	M
5	7/3	7/19	22	16	M
4	7/7	7/26	23	19	M
5	7/12	7/28	23	16	M
5	7/14	7/31	23	17	M
4	7/14	7/31	23	17	M
4	7/14	7/31	23	17	M
6	7/14	7/31	23	17	F
5	7/19	8/7	24	19	M
5	7/26	8/14	24	19	F
6	8/10	9/4	24	25	F
5	8/14	9/4	24	21	F
4	8/17	9/6	24	20	F
4	8/21	9/11	24	21	F

After the middle of September 1950, there remained 16 additional apparently normal larvae. All these individuals except one had from one to three larval molts during the second summer. The actual numbers of larval molts for this species varied from four to eight molts with five being the mode.

With the rearing work on tabanids coming to a close during the fall of 1950, the remaining 16 larvae were all preserved. Had they been allowed to continue some might have emerged as adults with a 3-year cycle. Although it is unusual for tabanid larvae to hibernate more than two winters, Schwardt (1932) states that an occasional larva of *Tabanus atratus* may hibernate three winters before becoming an adult.

SUMMARY.—Limited observations were made on the horsefly, *Tabanus giganteus* Degeer during two successive seasons. Only 13 adults were collected but observations made on these and others not collected indicated rather definite adult habits. They attacked the backs of cattle, had an affinity towards entering vehicles or buildings, and were frequently seen alighting and resting on the warm hood of a car during cool damp mornings. From a single engorged female, a fertile egg mass was obtained. It was unusual in being orange-yellow in color. Each egg was yellow with two orange bands. The larvae are almost identical in color and size to larvae of *T. sulcifrons* but can be distinguished by pubescent markings on the anal segment. Seventeen individuals were reared to adults from these eggs and all had a two-year life cycle. The remaining 16 larvae, which might have emerged as adults on the third year had they been reared through, were preserved.

LITERATURE CITED

Schwardt, H. H. 1932. Biology and control of the black horsefly. Arkansas Agr. Expt. Sta. Bul. 280: 42.

Control of Corn Earworm and Rice Weevil in Dent Corn with DDT-Mineral Oil Emulsions

W. A. DOUGLAS[1] and C. E. SMITH[2]

The corn earworm, *Heliothis armigera* (Hbn.), and the rice weevil, *Sitophilus oryza* (L.), are considered the most important pests of corn in most, if not all, of the Gulf coast area. During 1952 an experiment was conducted on the Louisiana Agricultural Experiment Station Farm at Baton Rouge to determine whether these insects could be controlled in dent corn by applying emulsion sprays containing DDT and mineral oil. The experimental planting was located in the proximity of barns containing weevil infestations. The corn was allowed to remain in the field until November 14, fully a month later than the usual corn-harvesting date in this area, to give ample opportunity for weevil infestation to develop. Heavy earworm infestation was common to the area.

Table 1.—Control of corn earworm and rice weevil in dent corn with DDT-mineral oil emulsions and effect of treatment on pollination.

DDT	Mineral Oil	Ears Undamaged by Corn Earworm	Ears Not Infested by Rice Weevil	Ears Incompletely Pollinated
Pounds	*Gallons*	*Per Cent*	*Per Cent*	*Per Cent*
1.2	1	100	100	22
	1.6	98	100	28
0.8	1	99	100	22
	1.6	99	99	16
Check (untreated)		4	71	14

The experimental plots were planted to Louisiana hybrid 521 on May 9, 1952. There were five treatments, with five replicates of each treatment arranged in five randomized blocks. The corn was planted, fertilized, and cultivated in the usual manner. Beginning when 15 per cent of the silks had appeared, three applications of each of four emulsions were made on July 11, 14, and 17, with a compressed-air sprayer at a pressure of 40 pounds per square inch with a *Tee Jet 650067* nozzle, at the rate of 20 gallons per acre.

Four formulations were used—DDT at 1.2 and 0.8 pound each with 1 and 1.6 gallons of oil in 20 gallons of water containing 0.5 per cent of an emulsifier. The mineral oil had a Saybolt viscosity of 80–90 seconds of 100° F.

Twenty-five ears of corn were harvested per replicate, or 125 ears per treatment, on November 14. Each ear was examined for corn earworm damage, rice weevil infestation, and effect of the treatment on pollination. The results are summarized in table 1.

All four emulsions gave almost perfect control of the corn earworm and almost complete prevention of rice weevil infestation.

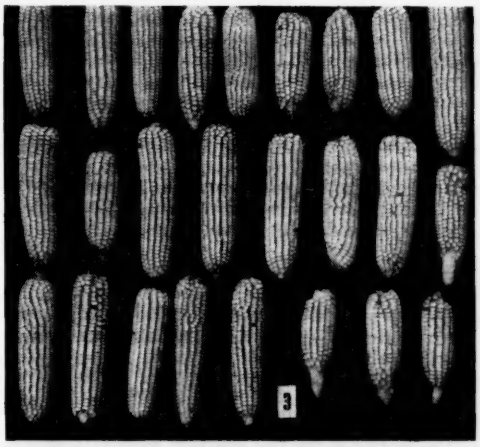


FIG. 1.—Corn from plot treated with an emulsion containing 0.8 pound of DDT and 1 gallon of oil per acre, showing relatively no injury by corn earworm and rice weevil.

Interference with pollination was slight and probably could have been reduced, if not eliminated, by the use of smaller dosages. Previous spray tests with hand equipment have indicated that one-third of the amount of spray used in this experiment will give good control of the corn earworm. Therefore, this experiment may be considered a very severe test of the effect of DDT-oil emulsion sprays on pollination of corn.

There was no injury by insects other than the corn earworm and rice weevil in any of the treated plots. In contrast, of the 125 ears from the untreated check plots, 37 showed injury by other insects. Some of this injury was caused by the fall armyworm, *Laphygma frugiperda* (A. & S.), and the pink corn worm, *Pyroderces rileyi* (Wals.). The check plots also showed injury caused by rot-producing organisms and considerable loss from birds feeding on the insects during the growing season and later on

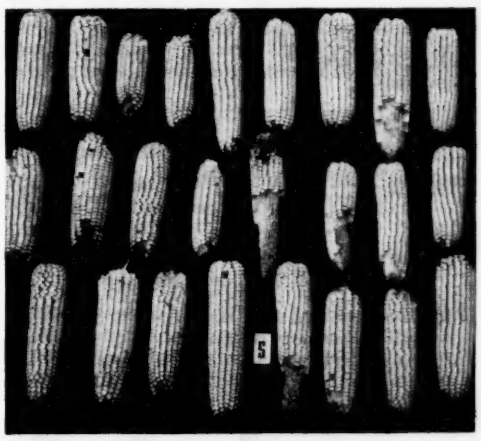


FIG. 2.—Corn from untreated check plot, showing injury to tips of ears by the corn earworm, emergence holes of the rice weevil, damage by disease organisms, other insects, and birds.

[1] Entomologist, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, United States Department of Agriculture.

[2] Entomologist, Louisiana Agricultural Experiment Station.

the exposed kernels. In feeding on earworm larvae the birds leave the husk in a ragged condition, which exposes the kernels. They continue feeding on these kernels until the corn is harvested. None of this injury occurred in the treated plots.

The over-all quality of the treated corn was much superior to that in the check plots, as may be noted in figures 1 and 2.

Caution: Parts of corn plants contaminated with DDT should not be fed to dairy animals or to animals being finished for slaughter.

Tests of Insecticides for Control of Chestnut Weevil Larvae in the Soil

E. R. VAN LEEUWEN, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

The larvae of the two chestnut weevils, *Curculio auriger* Casey and *C. proboscideus* F., after completing their growth in the nuts, enter the soil beneath chestnut trees, where they build earthen cells in which they transform into adults. Some individuals may remain in the soil as long as 45 months. Since 1948 the Bureau of Entomology and Plant Quarantine has been conducting experiments at Beltsville, Maryland, to find an insecticide that might be used to destroy the insects while they are undergoing transformation in the soil. One series of tests was made with several of the new organic insecticides and another series with fumigants. The results of these studies are reported in this paper.

Table 1.—Results of laboratory tests with several organic insecticides against larvae of the chestnut weevil.

Material	Active Ingredient in Pounds per Acre	Per Cent Mortality	
		Small Weevils	Large Weevils
Toxaphene	2	52	80
	5	44	60
	10	64	100
	20	44	80
	25	40	60
BHC (25 per cent gamma)	5	47	80
	10	72	100
	15	100	100
	20	100	100
	25	100	100
Chlordane	5	46	80
	10	50	80
	15	49	80
	20	62	100
	25	48	80
Parathion	½	84	89
	1	90	93
	2	100	100
	4	100	100
	6	100	100
	8	100	100
	10	100	100
	25	100	100
Check (untreated)	—	16	64

TESTS WITH ORGANIC INSECTICIDES.—In the laboratory the test materials were intimately mixed with screened Collington fine sandy loam taken from a chestnut orchard at Glenn Dale, Maryland. The prepared soil was then placed in either a 10-inch flower pot or a 2-gallon tin pail the bottom of which was perforated. Checks were set up which contained no insecticide. On the top of each pot 50 small and 5 large chestnut weevil larvae from storage outdoors were permitted to burrow into the soil. After 30 days the soil was examined for larvae. The results, given in table 1, show that chlordane and toxaphene were not so effective as BHC and parathion.

In further laboratory tests soil was treated with various dosages of parathion and 2 months later chestnut weevil larvae were liberated on the surface and allowed to burrow in. After an exposure of a month the soil was examined to determine the effectiveness of the treatment. The results were as follows:

	Per cent mortality	
Pounds per acre	*Small larvae*	*Large larvae*
½	84	93
1	97	99
2	90	95
4	98	80
6	100	100

These data indicate that parathion evaporates rapidly and that 6 pounds per acre is necessary to kill 100 per cent of the larvae.

In field test soil plots 20 by 20 feet in a chestnut orchard at Glenn Dale were treated with insecticides either by spraying or by mixing the material with dry sand and then distributing it on the surface by hand. The plots were then disked twice to a depth of 5 inches. Several untreated areas were also disked to be used as checks. A total of more than 40,000 small and 800 large chestnut weevil larvae were liberated on the surface of the soil. Other smaller plots were treated by mixing parathion with the soil by hand to a depth of 5 inches to give an intimate mixture similar to that used in the laboratory. All the insecticides were applied and the larvae liberated in the fall, and the larvae were recovered the following spring.

Table 2 shows that parathion mixed by hand with the soil was the only promising treatment. However, hand mixing is not practical because of the labor required. Parathion shows some promise as a soil insecticide if a method of incorporating it in the soil is developed.

TESTS WITH FUMIGANTS.—In laboratory tests 12-inch flower pots were filled with Collington fine sandy loam from a chestnut orchard and 50 small chestnut weevil larvae were permitted to burrow into the soil. The following fumigants were then applied: parathion, carbon bisulfide, and dichloroethyl ether at dosages from 25 to 65 pounds per acre; ethylene dibromide at 5 to 85 pounds per acre; and D-D mixture at 10 to 45 pounds per acre. To facilitate the application of small dosages, the fumigants were mixed with acetone, 1 part to 272 parts. The mixture was injected 5 inches deep into the center of the pot. Examinations by screening the soil in the pots were made at the end of a month and at various intervals thereafter. All dosages of ethylene dibromide except the two lowest (5 and 10 pounds per acre) and D-D at 25 to 45 pounds per acre killed 100 per cent of the larvae. The other

Table 2.—Results of field tests with several organic insecticides against chestnut weevil larvae in the soil.

Material	Method of Distribution	Active Ingredient in Pounds per Acre	Per Cent Reduction	
			Small Weevils	Large Weevils
Chlordane	Sprayed	50	0	33
		60	2	17
		70	41	33
		80	50	33
		90	21	25
		100	15	42
BHC (25% gamma)	Sprayed	5	25	0
		10	13	27
		20	19	36
		30	11	45
		40	18	73
Parathion	Sprayed	5	7	17
		10	15	50
		20	14	0
		30	30	33
		40	46	47
		50	45	33
	Mixed with sand	5	0	9
		10	33	18
		20	25	36
		30	16	18
		40	5	73
		50	28	9
	Mixed by hand	5	79	73
		10	98	100
		20	100	100
		30	100	100
		40	100	100
		50	100	100

fumigants were less effective, but dichloroethyl ether killed more than 9 per cent at 55 pounds per acre. Acetone alone in comparable quantities was found to be nontoxic.

In field tests small chestnut weevil larvae were liberated in lots of approximately 200 on 1-square-foot areas of orchard soil immediately after leaving the nuts in the fall of 1949. These larvae, when building their cells, burrow straight down without lateral movement. In May 1950 these areas were treated with various quantities of ethylene dibromide, and 30 days later were examined for living larvae. The mortalities were as follows for larvae receiving different dosages:

Pounds per acre	*Per cent*
5	53
10	73
15	83
20	89
25	92
40	97

A larger series of tests was then made with two commercial fumigants, one containing 41 per cent of ethylene dibromide and the other D-D mixture. The applications were made in July 1950 and examined a month later. D-D gave 98 or 99 per cent kill at 8 to 12 gallons and the ethylene dibromide 99 per cent at 4 and 5 gallons and 100 per cent at all dosages above 9 gallons per acre.

In the fall of 1950 the same ethylene dibromide product was injected into the soil containing large chestnut weevil larvae. Injections were made 5 inches deep at the rate of 10 gallons per acre. The treatments were replicated four times and the check twice. The plots treated with the ethylene dibromide product showed a larval reduction of 98 per cent.

To determine how far from the point of application ethylene dibromide would diffuse and destroy the chestnut weevil larvae, several tests were made with a 1-ml. dosage injected 5 inches into the soil. Examination of these areas showed that 99 per cent of the larvae within 6 inches of the injection point were killed. Injections of 1 ml. at 12-inch spacings are equivalent to 10 gallons per acre.

To determine whether the fumigants were injurious to bearing chestnut trees, the soil beneath five 8-year-old trees growing in Collington fine sandy loam soil was treated with D-D at the rate of 25 pounds, and 10 similar trees were treated with the 41-per cent ethylene dibromide at 10 gallons per acre. The fumigants were injected into the soil to a depth of 5 inches at 12-inch spacings. In addition, parathion was used at 12.5, 25, 50, 75, and 100 pounds per acre. Each dosage was spread on the surface of the soil beneath five bearing chestnut trees and disked in to a depth of 5 inches. None of these trees were injured by the treatment.

SUMMARY.—The fact that chestnut weevil larvae remain for long periods in the soil beneath chestnut trees suggested treatment of the soil with insecticides as a means of control.

Toxaphene, BHC, chlordane, and parathion applied to the surface of the soil in the field and disked twice to a depth of 5 inches were not effective against the larvae. When intimately mixed with the soil by hand, parathion proved very effective, but this method of application was not practical.

Laboratory tests were made with carbon bisulfide, dichloroethyl ether, D-D, and ethylene dibromide as fumigants injected into the soil. Ethylene dibromide was the most effective material tested. Under field conditions, ethylene dibromide (41 per cent) gave excellent results when used at the rate of 10 gallons per acre. There was no injury to bearing trees growing in soil treated by this method.

Relation between Winter Temperatures, Boll Weevil Survival, Summer Rainfall, and Cotton Yields[1]

R. C. GAINES, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[2]

A study of the factors that influence boll weevil injury to a particular cotton crop should start with the conditions that existed during the preceding fall. Consideration should be given first to the supply of

[1] Presented at the meeting of the Cotton States Branch, American Association of Economic Entomology at New Orleans, La., February 9–11, 1953.

[2] The field work was performed by M. T. Young, G. L. Smith, G. L. Garrison, A. L. Scales, T. C. Barber, R. W. Howe, H. W. Lee, E. S. Tucker, H. C. Young, R. W. Moreland, F. F. Bondy, T. P. Cassidy, A. Thomae, A. J. Chapman, W. A. Stevenson, C. F. Rainwater, and a large number of temporary assistants.

feeding and breeding material for the boll weevil, *Anthonomus grandis* Boh., which is affected by weather conditions during August, September, and October, defoliation by chemicals or the cotton leafworm, *Alabama argillacea* (Hbn.), and the date of the first killing frost. The number and the condition of boll weevils entering hibernation are determined largely by the supply of feeding and breeding material prior to the general movement to hibernation quarters. The winter temperatures to which the weevils are exposed are affected by the shelter in which the insects overwinter, and these temperatures influence survival and emergence during the following spring and early summer. The weather in the spring also has a direct bearing on the number of weevils that live long enough to find cotton plants and reproduce. Summer rainfall also has an important effect on the rate of weevil multiplication.

Each of these factors constitutes a separate study. Discussions of some of them for the years 1915 to 1934 have been published (Gaines 1935; Young 1935). The U. S. Weather Bureau has also made extensive correlation studies of weather and weevils (Kincer 1928). The correlation studies presented in this paper are based on yearly records (Table 1) from 1915 to 1952 of weather conditions, boll weevil survival in various shelters, yield in treated plots, yield per planted acre, and total yield in Madison Parish, Louisiana, and they are a continuation of the studies from 1915 to 1941 which have been published (Gaines 1943). The results are interpreted on the basis of statistical significance at odds of 19 to 1.

WINTER TEMPERATURES AND BOLL WEEVIL SURVIVAL.—The number of days from September to March on which the temperature fell below 32° F. was correlated with the number of live boll weevils found in Spanish moss during the spring, the percentage surviving in hibernation cages, and the number found in cotton fields during May and June.

The number of days from September to March on which the temperature fell below 20° F. was cor-

Table 1.—Summary of winter temperatures, boll weevil survival, summer rainfall, and cotton yields, Tallulah, La., 1915 to 1952.

Year	Number of Weevils Entering Hibernation		Days from September to March When Temperature Fell Below—		Minimum Temperature For Winter °F.	Weevils Surviving the Winter			
	Per Ton of Spanish Moss	Per Acre of Ground Trash	32° F.	20° F.		Number per Ton of Spanish Moss	Per Acre of Ground Trash		Per Cent in Hibernation Cages
							Number	Per Cent	
1915–16	—	—	32	0	20	24.0	—	—	6.14
1916–17	—	—	45	5	16	8.0	—	—	.17
1917–18	—	—	60	14	1	1.7	—	—	.05
1918–19	—	—	45	4	9	4.0	—	—	.31
1919–20	—	—	39	2	18	9.5	—	—	.48
1920–21	—	—	35	1	16	22.0	—	—	1.38
1921–22	—	—	30	0	22.5	127.0	—	—	4.22
1922–23	—	—	26	0	20	19.0	—	—	1.59
1923–24	—	—	51	5	10.5	.5	—	—	.11
1924–25	—	—	49	4	15	.6	—	—	.01
1925–26	280	—	47	3	13	.0	—	—	.05
1926–27	242	—	30	4	16	4.0	—	—	—
1927–28	21	—	43	10	11	1.0	—	—	.02
1928–29	240	—	43	7	16	3.8	—	—	.78
1929–30	189	—	44	11	1.8	.2	—	—	.01
1930–31	49	—	37	0	20	33.0	—	—	5.34
1931–32	724	—	19	0	23	462.3	—	—	18.39
1932–33	881	—	28	3	12	1.3	—	—	.15
1933–34	365	—	29	0	20	40.8	—	—	7.51
1934–35	192	—	38	5	6	5.2	—	—	.11
1935–36	19	—	54	7	14	.0	141	—	.17
1936–37	141	2,118	31	0	22	23.0	50	2	11.87
1937–38	51	519	35	6	14	1.4	186	36	1.13
1938–39	4	1,284	33	3	15	6.7	226	18	1.16
1939–40	189	2,243	59	12	−8	.0	190	8	.01
1940–41	23	721	31	2	17	—	920	128	10.36
1941–42	—	1,484	46	4	11	—	327	22	.14
1942–43	—	2,916	29	4	14	—	750	26	1.40
1943–44	—	2,488	43	4	15	—	625	25	1.29
1944–45	—	2,435	34	0	20	—	1,512	62	15.42
1945–46	—	4,199	31	3	16	—	1,065	25	9.28
1946–47	—	2,698	34	2	18	—	426	16	1.84
1947–48	—	1,178	50	4	−2	—	177	15	.38
1948–49	—	2,146	27	1	10	—	1,710	80	4.04
1949–50	—	3,231	31	0	21	—	2,202	68	17.10
1950–51	—	4,586	48	8	−12	—	1,742	38	.02
1951–52	—	1,367	37	5	15	—	629	46	.94

Table 1.—*continued*

Year	Number of Weevils per Acre of Cotton Plants During May and June	Total Precipitation June 21 to August 19, in Inches	Days With 0.30 Inch or More Precipitation from June 21 to August 19	Per Cent Increase in Yield Over Checks in Treated Plots	Yield in Madison Parish	
					Pounds per Acre[1]	Total Number of 500-Pound Bales[2]
1915–16	346	9.18	7	—	—	5,385
1916–17	4	6.17	6	—	—	11,217
1917–18	51	2.96	5	—	—	13,725
1918–19	73	9.61	10	—	—	4,766
1919–20	81	6.92	8	32.8	—	5,716
1920–21	129	9.32	9	44.6	—	7,406
1921–22	133	14.62	16	83.9	—	4,475
1922–23	70	7.80	8	20.7	—	6,385
1923–24	10	1.39	2	1.1	—	12,550
1924–25	3	6.57	5	11.7	—	22,682
1925–26	32	8.62	12	68.3	—	15,449
1926–27	—	8.88	9	33.0	—	2,812
1927–28	9	9.05	11	41.2	220	11,402
1928–29	30	5.98	5	11.7	299	19,671
1929–30	12	1.65	2	9.3	205	15,488
1930–31	7	8.53	8	31.8	300	19,402
1931–32	247	7.25	7	45.7	225	14,447
1932–33	269	16.33	12	46.0	209	9,243
1933–34	439	2.52	2	19.5	252	10,516
1934–35	231	4.03	2	11.3	252	11,658
1935–36	14	5.85	6	5.0	453	24,130
1936–37	51	1.86	2	3.3	469	28,992
1937–38	97	10.77	9	9.6	414	18,306
1938–39	113	7.05	6	11.3	410	19,325
1939–40	35	12.22	12	54.7	177	7,997
1940–41	263	6.87	8	46.3	238	10,925
1941–42	44	5.08	5	2.4	430	21,393
1942–43	200	3.46	6	13.8	478	22,959
1943–44	110	6.02	7	1.8	482	21,610
1944–45	184	4.28	4	36.5	228	10,260
1945–46	359	13.44	10	75.0	116	5,409
1946–47	170	4.81	5	15.5	331	16,212
1947–48	91	14.89	6	13.7	449	23,039
1948–49	255	9.42	12	39.0	276	15,273
1949–50	560	7.66	10	112.8	373	14,423
1950–51	138	3.24	6	85.3	401	18,675
1951–52	123	1.65	1	18.4	—	—

[1] Data from Bureau of Agricultural Economics.
[2] Data from Census Bureau.

related with the percentage surviving in hibernation cages and the number found in cotton fields during May and June.

The minimum temperature for the winter was correlated with the percentage surviving in hibernation cages.

The number of boll weevils found in ground or woods trash in February and March, and the percentages surviving both in ground trash and in hibernation cages were correlated with the number found in cotton fields during May and June.

OVERWINTERED BOLL WEEVILS AND COTTON YIELDS.—The number of boll weevils found in ground trash during February and March, the percentage surviving in hibernation cages, and the number found in cotton fields during May and June were correlated with the percentage increase in yield over untreated checks in treated plots where boll weevils had been controlled with insecticides.

SUMMER RAINFALL AND COTTON YIELDS.—The total rainfall from June 21 to August 19 and the number of days on which there was 0.30 inch or more of rain were correlated with the percentage increase in yield in treated plots and total yield in Madison Parish.

The percentage increase in yield in treated plots was correlated with yield per acre and with total yield in Madison Parish. The yield per planted acre was likewise correlated with the total yield.

OVERWINTERED BOLL WEEVILS, SUMMER RAINFALL, AND INCREASED YIELDS IN TREATED PLOTS.—The variables used in multiple correlations were the ones having the greatest coefficients in simple correlations and are as follows: the number of weevils found in ground trash in February and March and the number found in cotton fields in May and June, the percentage surviving in hibernation cages and the weevils found in cotton fields in May and June, the number of weevils found in ground trash in February and March and the percentage increase in yield in treated plots, the number of weevils found in cotton fields in May and June and the percentage

increase in yield in treated plots, and the number of days with 0.30 inch or more of rainfall from June 21 to August 19 and the percentage increase in yield in treated plots. The multiple correlation coefficient for number of weevils found in ground trash in February and March, the number of days with 0.30 inch or more of rainfall from June 21 to August 19, and the percentage increase in yield in treated plots was 0.83; for the number of weevils found in cotton fields in May and June, the number of days with 0.30 inch or more of rainfall from June 21 to August 19, and the percentage increase in yield in treated plots it was 0.78; and for the percentage surviving in hibernation cages, the number of days with 0.30 inch or more of rainfall from June 21 to August 19, and the percentage increase in yield in treated plots it was 0.69. All records used in the multiple correlations were for the 17-year period 1936 through 1952.

LITERATURE CITED

Kincer, J. B. 1928. Weather and the cotton weevil. U. S. Monthly Weather Rev., **56:** 301–4.

Gaines, R. C. 1935. Cotton boll weevil survival and emergence in hibernation cages in Louisiana. U. S. Dept. Agr. Tech. Bul. **486.**

Gaines, R. C. 1948. Relation between winter temperatures, boll weevil survival, summer rainfall, and cotton yields. JOUR. ECON. ENT. **36** (1): 82–4.

Young, M. T. 1935. Boll weevil control with calcium arsenate on field plots in Madison Parish, La., from 1920 to 1934. U. S. Dept. Agr. Tech. Bul. **487.**

Further Evidence of Tuber Damage by the Western Potato Flea Beetle[1]

H. R. MACCARTHY,[2] *Laboratory of Entomology, Kamloops, B. C.*

The western potato flea beetle, *Epitrix subcrinita* (Lec.),[3] is the only important species of flea beetle attacking potatoes in the Cariboo district of British Columbia. The larval diet is not known with certainty, but in a weed-free potato field it must be presumed to consist of underground parts of the potato plants. The writer (1950) showed, in laboratory experiments, that the larvae were not only capable of damaging rhizomes and roots but also caused tuber damage similar to that produced by the tuber flea beetle, *Epitrix tuberis* Gent.

The same conclusion was reached on the basis of field observations by Webster and Baker (1929) and by Webster (1932), in western Washington. Experimental work by Jones (1944) showed that nearly all economic loss could be attributed to *E. tuberis*. Landis (1948) demonstrated that both species could propagate on several host plants. The last two papers include reviews of literature.

During 1950–52, *Epitrix subcrinita* increased steadily in numbers in the Soda Creek area of the Cariboo district, British Columbia. *E. tuberis* has not yet been recorded in the Cariboo district. Population samples from untreated potato fields were taken in these years at approximately weekly intervals from June to September on three farms. The collecting stations were 10 miles apart, along the main north-south road.

[1] Contribution No. 3086, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.
[2] Field Crop Insect Section.
[3] Determination by Dr. L. G. Gentner, Medford, Oregon.

The increase in the infestation is recorded in table 1, which indicates also the two population peaks representing the emergence of the two summer generations. In fields 1 and 2 the numbers of flea beetles increased from 1951 to 1952, and as the seasons progressed. In these fields only slight damage occurred, consisting mainly of the familiar "shot hole" effect on the leaves, caused by feeding of the adults. In 1951 in field 3 there was evidence of tunneling in tubers by larvae and a few tracks were seen.

Table 1.—Numbers of adults of *Epitrix subcrinita* taken per 100 strokes of a 15-inch net at approximately weekly intervals in 3 fields, Soda Creek, B. C., 1951 and 1952.

	FIELD 1		FIELD 2		FIELD 3	
	1951	1952	1951	1952	1951	1952
June	—	—	0	—	—	10
	0	—	—	—	—	1
July	0	0	1	4	50	42
	0	0	1	6	58	214
	5	3	3	8	13	275
	0	0	0	—	16	68
	0	0	4	—	—	—
	—	2	—	—	—	—
Aug.	5	4	6	15	24	101
	39	7	13	6	118	157
	14	30	253	42	351	8,221
	14	82	85	105	1,514	11,280
	—	620	74	53	1,713	20,880
Sept.	11	—	65	371	1,482	7,520
	—	—	90	65	—	—

In 1952 the number of adults in field 3 rose to extraordinary levels. Within a few days of the emergence of the second summer generation in August, the leaves were skeletonized. For an estimate of the damage, a random sample of 150 tubers was taken in early September. One tuber was dug from a plant on crossing every fourth row on a zigzag course across the width of the field. In this way a sample was obtained that was representative of all the types of slope and soil in the field.

The damage was appraised at the Kamloops laboratory, in the standard manner for injury inflicted by *Epitrix tuberis*. The method consists in peeling each tuber thinly and counting the damage marks thus revealed. For the most part these were tunnels lined with wound cork, often surrounded by a yellow halo. The few surface tracks were consistently shallower than those caused by *Epitrix*

Table 2.—Tubers marked by larval feeding of *Epitrix subcrinita* in a heavily infested field, Soda Creek, B. C., 1952.

MARKS PER TUBER	NUMBER OF TUBERS
0	7
1–4	47
5–9	43
10–14	28
15–19	10
Over 20	15
	150

tuberis. Tubers were placed in six categories (Table 2). For commercial purposes, 10 marks or more would put tubers into a lower grade unless potatoes were in unusually short supply. Table 2 shows that uncontrolled populations of *E. subcrinita* are capable of causing economic loss by damaging tubers.

LITERATURE CITED

Jones, E. W. 1944. Biological studies of two potato flea beetles in eastern Washington. JOUR. ECON. ENT. 37(1): 9–12.

Landis, B. J. 1948. Plants upon which tuber flea beetles and western potato flea beetles propagate. JOUR. ECON. ENT. 41(1): 6–9.

MacCarthy, H. R. 1951. A comparison of potato tuber damage by two flea beetles, *Epitrix tuberis* Gent. and *Epitrix subcrinita* (Lec.) (Coleoptera: Chrysomelidae). Proc. Ent. Soc. British Columbia 47: 42.

Webster, R. L. 1932. Injury and distribution of potato flea-beetle in Washington. JOUR. ECON. ENT. 25(5): 976–80.

Webster, R. L. and W. W. Baker. 1929. Potato flea-beetles in Washington. *Epitrix subcrinita* Leconte: *Epitrix cucumeris* Harris. JOUR. ECON. ENT. 22(6): 897–900.

Tests with Aerosols for Control of the Pea Aphid

TOM A. BRINDLEY and RALPH SCHOPP, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Liquefied-gas aerosols have been tested for control of the pea aphid, *Macrosiphum pisi* (Kltb.), in several pea-growing areas of the United States. In Maryland Ditman and co-workers (1944) demonstrated that the aerosol method of applying some insecticides was highly effective against this aphid. In Virginia Anderson & Hofmaster (1948) found that DDT and benzene hexachloride in aerosol form gave good control. In Wisconsin Bronson & Dudley (1949) found that aerosols gave good control but that dusts appeared to be more practical.

Exploratory experiments conducted by the authors in 1947 indicated that good control of the pea aphid in the Pacific Northwest might be expected from the use of aerosols.

In 1948 a series of experiments was carried out with four aerosols containing the following materials: (1) 5 per cent of DDT (aerosol grade) plus 10 per cent of methylated naphthalene in methyl chloride, (2) 10 per cent of a 40-per cent solution of TEPP (tetraethyl pyrophosphate) in methyl chloride, (3) 10 per cent of the 40-per cent TEPP solution plus 10 per cent of acetone in Freon-12, and (4) 10 per cent of methyl isobutyl ketone plus 10 per cent of acetone in Freon-12. The technique outlined by Fulton *et al.* (1947) was used in preparing cylinders of the aerosol solutions. The first two of these aerosols were applied alone at about 40 pounds per acre. The other two were applied at about 10 pounds per acre mixed with 20 pounds of 5-per cent DDT dust. Freon-12 was used in the aerosols applied with dust in order to eliminate the danger of fire from the static charges in the fan housing of the duster.

[1] In cooperation with the Idaho, Washington, and Oregon Agricultural Experiment Stations. The authors are indebted to Floyd F. Smith for helpful suggestions.

For applying the aerosols alone, 18 oil-burner nozzles with a capacity of 2 gallons per hour were placed in a single row along the 25-foot boom of a power duster as shown in figure 1. They were fastened so as to project down and toward the rear of the machine at an angle of about 45 degrees. The boom was covered with the usual canvas trailer.

For applying the aerosols with 5-per cent DDT dust, an oil-burner nozzle capable of delivering 9 gallons per hour was used to release the aerosol into the air inlet of the dusting machine. In this manner the aerosol came in contact with the dust as it flowed through the fan housing while it was being applied. In previous tests TEPP solution dripped into the dust in the fan housing increased the kill of aphids but often resulted in clogged booms. It was thought that perhaps the TEPP aerosol would be as effective and avoid clogging of the booms.

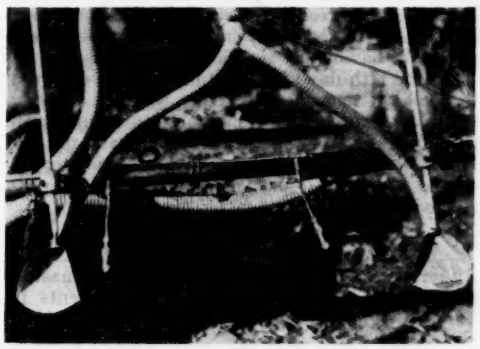


FIG. 1.—Arrangement of aerosol nozzles on a conventional-type duster boom so that either a dust or an aerosol or both could be applied.

Methyl isobutyl ketone has been used in the laboratory to cause pea aphids on samples of vine tips to release their beaks from the foliage so that they could be sifted onto a counting board to facilitate counting. It was therefore thought that, if applied with DDT dust, this material might cause the aphids to leave the inaccessible parts of the foliage and be more readily killed by the DDT.

To aid in determining the value of the aerosols, DDT and TEPP dusts were also tested. The dusts were applied at about 20 pounds per acre.

Table 1.—Effectiveness of various aerosols and dusts, applied alone and together, against the pea aphid.

TREATMENT	NUMBER OF SURVIVING APHIDS		PER CENT CONTROL	
	Oregon	Idaho	Oregon	Idaho
Aerosols alone (methyl chloride):				
TEPP 4%	44	139	97	98
DDT 5%	181	165	90	97
Dust alone:				
TEPP 1%				
Proprietary	—	85	—	99
Laboratory-prepared	—	64	—	99
DDT 5%	132	164	92	97
Aerosols (Freon-12) with 5% DDT dust:				
TEPP 4%	151	232	91	96
Methyl isobutyl ketone	413	363	76	94
Check (no insecticide)	1738	6086	—	—
Difference required for significance	222	[1]	13	[1]

[1] Not significant according to the *F* test.

At each place five replicates were made in 0.05 acre plots arranged in randomized blocks. The aerosols and dusts were applied at Milton, Oregon, on June 26 and at Joel, Idaho, on July 17. Control was determined by counting the surviving aphids on samples of 20 vine tips taken at random from each plot 5 days after the insecticides were applied.

The results, given in table 1, show that methyl isobutyl ketone and TEPP aerosols were of little additional value when applied with the DDT dust. Differences between DDT dust, the DDT aerosol, and the TEPP aerosol were too small to be considered as having any significance.

On the fifth day after treatment it was observed that all the aerosol treatments, whether alone or with dust, caused some plant injury. Injury from the TEPP aerosol was greater than that from the DDT aerosol. Methyl isobutyl ketone aerosol caused the least injury. The aerosol-treated peas seemed to have matured faster than the others.

LITERATURE CITED

Anderson, Lauren D. and Richard N. Hofmaster. 1948. Pea aphid control experiments in Virginia in 1947. JOUR. ECON. ENT. **41**(2): 278–82.

Bronson, T. E. and J. E. Dudley, Jr. 1949. Liquefied-gas aerosols for pea aphid control. JOUR. ECON. ENT. **42**(4): 661–3.

Ditman, L. P., Floyd F. Smith, Lyle D. Goodhue, and T. E. Bronson. 1945. DDT aerosols for pea aphid control. JOUR. ECON. ENT. **38**(2): 183–8.

Fulton, R. A., F. D. Berlin, and R. S. Bochert, Jr. 1947. A laboratory method for filling aerosol containers, U. S. Bur. Ent. and Plant Quar. ET-245, 4 pp.

The Biology and Control of the Nantucket Pine Moth and the European Pine Shoot Moth[1]

L. A. STEARNS,[2] *Delaware Agricultural Experiment Station, Newark*

Pines are an attractive and distinctive feature of Delaware's landscape. Highways in the central and southern portions of the State, which lie within the Coastal Plain, extend for miles through natural stands of loblolly pine (*Pinus taèda* Linn.). Hillsides, in the northern, Piedmont section, are dotted with young growths of red pine (*P. resinòsa* Ait.).

According to Taber (1937), loblolly is commercially the most important pine in this area since it is the principal source of manufactured lumber. Red pine, although indigenous to northern United States, is a comparatively recent introduction. Thus far, it has served chiefly as a cover for water-sheds and in windbreaks on large farms and estates. Both species are now being used extensively and successfully for reforestation purposes.

The Nantucket pine moth, *Rhyacionia frustrana* (Comst.), has been recognized locally as a serious pest on loblolly pine for many years. Its control, except on nursery stock, has been considered impracticable, because large acreages were commonly involved and suggested remedial measures were far from satisfactory.

Since about 1938, red pine has been increasingly subject to attack by this insect and, even more severely, by the European pine shoot moth, *Rhyacionia buoliana* (Schiff.). Again, in this case, seldom have attempts been made to reduce injury for the reasons already stated. The need for adequate means to prevent excessive damage to individual trees and group-plantings prompted studies in 1948, 1949, and 1950, which are discussed briefly herein.

Entomological literature includes numerous publications covering the life history, habits, and control of both *Rhyacionia frustrana* and *R. buoliana*. The more essential facts have been summarized conveniently for the reader by Craighead (1949).

In the Middle Atlantic states (southern New York to northern Virginia), *R. frustrana* is known to have two generations each year; it overwinters in the pupal stage; and moths reportedly are active from about mid-April to mid-May and, again, in late June and early July. *R. buoliana*, on the contrary, has but one generation annually; it hibernates as a partially-grown larva; and the moths reportedly appear during June and early July.

The research under consideration had three objectives: first, to evaluate certain of the newer insecticides as potential controls; second, to determine the exact emergence periods of both species under Delaware conditions; and, third, to develop a suitable application-schedule for the mixed population on red pine.

Friend & West (1933) recommended that, whenever feasible, all tips infested by shoot-moth larvae be cut off and burned, preferably during May. Spraying has been advocated as a substitute for this laborious practice of questionable efficacy and doubtful acceptance. Hamilton (1931) reported favorable results from three sprays of Penetrol (1–200) plus Black Leaf 40 (1–500) applied on June 16, 23, and 30. Friend & Hicock (1933) stated that a spray mixture of summer oil (2 gals.), lead arsenate (3 lbs.), and water (95 gals.), applied at 10-day intervals beginning about June 10, would probably provide the desired control.

A windbreak on a suburban property near Wilmington[3] was made available in 1948 for control tests. Included were some 250 red pines from 4 to 8 feet in height, moderately and uniformly infested by *Rhyacionia buoliana* and supporting, also, a relatively much smaller but sizeable population of *R. frustrana*. It was divided into six areas of about 40 trees each. Five of these received, respectively, the following 50-gallon treatments: (1) Black Leaf 40 (16 fl. oz.) and Grasselli Spreader-Sticker (4 fl. oz.)—equal to New Jersey recommendation; (2) summer oil (Volck, 1 gal.) and lead arsenate (1.5 lbs.)—the Connecticut recommendation; (3) benzene hexachloride (1.5 lbs. 6 per cent gamma); (4) parathion (10 oz. 25 per cent w.p.); (5) DDT (1 lb. 50 per cent w.p.). The sixth served as a check. Three applications, timed to combat *R. buoliana* were made: the first on June 11, the date of first emergence; the second on June 22, the date of maximum moth activity; and the third on July 8, the date of last emergence.

There was no evidence of phytotoxicity from any

[1] Published as Miscellaneous Paper No. 170, with the approval of the Director of the Delaware Agricultural Experiment Station. Publication 253 and Scientific Article 175 of the Department of Entomology, February 19, 1953.

[2] Professor and Department Chairman, Entomology.

[3] Owner, William M. D. Bryant; equipment and labor furnished by the local office of the F. A. Bartlett Tree Expert Company (R. M. Viggars, Divisional Manager, cooperating).

of the treatments except the lead arsenate-oil mixture. After the second application, the trees which had received this combination showed considerable injury, followed by a heavy drop of needles in the late summer and fall. However, gradual recovery was noted during the following growing season.

All treatments proved effective against *Rhyacionia buoliana*. On October 19, when the final 1948 examination was made, no shoot-moth larvae were found anywhere except on the unsprayed checks, which still were badly infested.

However, second-generation, wintering pupae of *Rhyacionia frustrana* were present generally in varying abundance. Infestation by this species, which previously had been somewhat obscured by the more conspicuous injury of *R. buoliana*, was now readily apparent. Only in the DDT and the parathion-treated areas were the numbers of pine-moth larvae reduced substantially by the June and July sprays for control of the shoot-moth larvae.

The emergence periods of *Rhyacionia frustrana* (1950) and that of *R. buoliana* (average from 1948, 1949, and 1950 observations), based on weekly-recorded data, are shown graphically in figure 1. The first moths of the spring brood of *R. frustrana* appeared between March 28 and April 5; 50 per cent had issued by May 12; and emergence was complete on June 6. The first moths of the summer brood of this species appeared between July 7 and 11; 50 per cent had issued by July 21; and emergence was complete on August 10. Comparable observations were not made in 1949 and 1948.

The first moths of the single summer brood of *Rhyacionia buoliana* were recorded on June 13, in 1950; 50 per cent had emerged by June 26; and emergence was complete on July 11. The dates in 1949 were June 14, June 19, and July 11, respectively; and, in 1948, June 11, June 22, and July 8, respectively. It is evident that these two moths must be dealt with for a period of approximately 4.5 months (March 25 to August 10) on red pine.

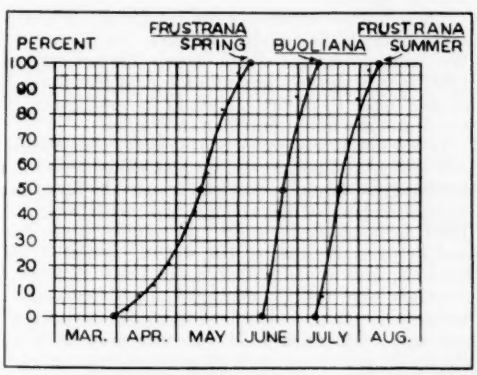


FIG. 1.—Emergence periods of *Rhyacionia frustrana* on loblolly pine, Dover, Delaware, 1950, and that of *R. buoliana* on red pine, Centerville, Delaware, 1948–49–50.

The following observations incidental to the recording of emergence seem worthy of comment. There is a striking difference in the mode of attack by pine-moth larvae as compared with that by shoot-moth larvae, a point unstressed in previous papers. The eggs of both insects are laid near the tips of the twigs on either the needles, buds, or shoots; and the larvae bore into the bases of the needles and, also, into the buds and shoots. However, injury by *Rhyacionia frustrana* alone usually results from multiple infestations on a terminal, whereas that by *R. buoliana* alone almost invariably is due to but a single one. This disparity in habits is emphasized by the data for *R. frustrana* included as table 1. Although only one larva had matured in each of three-fourths of the terminals examined, two had completed their development in one-fifth of them, and one terminal had actually provided sufficient food for seven larvae.

Table 1.—Variation in number of *Rhyacionia frustrana* larvae per loblolly-pine terminal, Dover, Delaware, 1949–50.

Number of Larvae per Terminal	Terminals Infested	
	Number	Per Cent
1	1399	73.44
2	359	18.85
3	108	5.67
4	25	1.31
5	10	0.52
6	3	0.16
7	1	0.05
Totals	1905	100.00

Another item of interest is the fact that, although larval parasites reportedly have proved rather effective in limiting the activities of both moths, none were encountered in these studies. Their absence may partially account for the present abundance of these pests.

Various circumstances restrict the full use of the controls for *Rhyacionia frustrana* and *R. buoliana* now available. It is essential to recognize these limitations and to work within them. The populations of both insects are largest and injury is of greatest importance in young pines. Damage decreases proportionately as trees approach maturity; eradication becomes impossible; spraying is ineffectual; and control costs are prohibitive. Results in 1949 from aerial applications of DDT, not discussed herein, can only be described as most disappointing. These treatments had no measurable effect on the numbers of *R. frustrana* in an 11-year-old, 5-acre, loblolly tract. It seems advisable, therefore, to write off well-established stands as a re-infestation liability concerning which little or nothing can be done, and to confine control operations to ornamental and other plantings during the early years of their growth when such efforts may be well rewarded.

Control, by the removal and destruction of infested twigs each year, depends on the ability of an individual to locate, not just a few or even many of the inhabited terminals, but practically every one of them. The brown, crooked, red-pine shoot resulting from feeding by a single *Rhyacionia buoliana* larva readily attracts attention, but the slightly off-color brittle tip on either red or loblolly, usually containing more than one *R. frustrana* larva or pupa, is less easily detected. This practice, if carried out about May 25, the most favorable time in Delaware for reducing the population of *R. buoliana*, would be more than one month and a half late for affecting similarly that of *R. frustrana*. If completed about

April 10 against *R. frustrana*, few of the still only partially-grown larvae of *R. buoliana* would have left their burrows in last year's growth, attacked developing shoots, and produced by then the characteristic injury described above.

The procedure, just considered, undoubtedly should be included in any program for control of these insects. However, chief reliance should be placed in spraying with DDT (rather than parathion, because of its longer residual effect) at 1 pound of active ingredient in 100 gallons of water using ground equipment. An application-schedule to cope with a moderate to large mixed population on red pine would require nine treatments—one at the 50 per cent point on the emergence curve for each of the three broods shown in figure 1 (see accompanying text for dates) and two others, the first about 14 days prior to and the second about 14 days subsequent to each of those three points. In the case of *Rhyacionia buoliana* alone on red pine or *R. frustrana* alone on loblolly, the number of applications should be reduced to conform with the indicated periods of emergence in each case. Since the completion of these studies, the adoption of such recommendations has met with success.

LITERATURE CITED

Craighead, F. C. 1949. Insect enemies of eastern forests. U.S.D.A. Misc. Pub. **657**: 466–9.

Friend, R. B. and H. H. Hicock. 1933. The European pine shoot moth. Conn. Agr. Expt. Sta. Circ. **90**: 29–31.

Friend, R. B. and A. S. West, Jr. 1933. The European pine shoot moth (*Rhyacionia buoliana Schiff.*) with special reference to its occurrence in the Eli Whitney forest. Yale Univ., School Forestry Bul. **37**.

Hamilton, Clyde C. 1931. Tests on the control of several insects attacking ornamental plants. JOUR. ECON. ENT. **24**(1): 162–9.

Taber, William S. 1937. Delaware trees, a guide to the identification of the native tree species. Del. State Forestry Dept. Pub. **6**: 23 & 27.

A Method for Eradication of the Mite, *Myocoptes musculinus*, from Laboratory Mice[1]

RICHARD D. STONER and WILLIAM M. HALE
From the Division of Bacteriology and Virology Medical Department, Brookhaven National Laboratory, Upton, L. I., N. Y.

The Listrophorid mite, *Myocoptes musculinus*,[2] frequently becomes a serious problem in raising laboratory mice. There are no reports in the literature concerning effective control of this parasite. A *Myocoptes* infestation may remain light and unrecognized in mouse colonies where there is a rapid turnover of experimental animals. However, the infestation may become intense and cause considerable trouble in long-term projects and in experimental work with debilitating diseases.

In our colony the problem necessitated eradication of the parasites rather than temporary control. The use of usual control measures and a number of the more commonly recognized insecticides and miticides failed. We, therefore, turned to a consideration of the miticide, di-(*p*-chlorophenyl) methylcarbinol[3] (DMC). This compound was first synthesized by Bergmann and Bondi in 1931 and, later, prepared by Grummitt *et al.* who used improved methods of synthesis. Waters & Witman demonstrated that DMC possesses a high initial and a residual toxicity for two-spotted mites, European red mites, red spiders, and Pacific mites. This suggested to us that DMC might prove to be an effective miticide for the *Myocoptes* mite.

Grummitt reported on the high specificity of the miticidal action of the di-(*p*-halophenyl) alkylcarbinols. This group of compounds was tested against many insects, and found effective only upon mites at practical levels of concentration. Grummitt tested various analogues and derivatives of the di-(*p*-halophenyl) alkylcarbinols and reported that the ring halogens were necessary for maximum acaricidal activity. He found that isomeric carbinols with one or both of the halogens in the ortho position demonstrated less activity. A shift in position of the alcohol group from the tertiary carbon atom resulted in loss of acaricidal activity in isomeric B-β-di-(*p*-chlorophenyl) ethanol.

Table 1.—Acaricidal activity of di-(p-chlorophenyl) methylcarbinol and toxicity for mice. Animals were treated three times at 5-day intervals.

DMC in Per Cent	Ethyl Alcohol in Per Cent	No. Mice Treated	No. of Deaths	Acaricidal Effect
0.4	95	10	7	All dead
0.4	50	36	4	All dead
0.2	50	44	0	All dead
0.1	50	14	0	A few survivors
0.05	50	14	0	A few survivors

There are no reports concerning the use of DMC as a miticide for mites, parasitic on mammals. We have investigated the acaricidal activity of DMC for *Myocoptes musculinus*. It is the purpose of this paper to report a method for eradication of the *Myocoptes* mite from laboratory mice.

In our initial trials of various insecticide and acaricide sprays and powders, it became evident that the active agent should be carried through the fur to the base of the hair for maximum contact with the mites. DMC is insoluble in water and soluble in alcohols and ketones. Because of the wetting action of the alcohols, several concentrations of DMC in alcohol solutions were tested for acaricidal activity. DMC, technical grade, was dissolved in 95 per cent and 50 per cent ethyl alcohol. It was necessary to bring the DMC into solution in 95 per cent ethyl alcohol and then dilute to 50 per cent with distilled water.

The toxicity for mice and toxicity for mites of various concentrations of DMC in alcohol are shown in table 1. We found 0.2 per cent DMC in 50 per cent alcohol satisfactory as a *Myocoptes* miticide. The mice were submerged in the DMC solution and scrubbed about the ears, eyes, and mouth with a cotton pad saturated with the solution. The animals were treated in this manner 3 times at 5-day inter-

[1] This research was done under the auspices of the Atomic Energy Commission.

[2] We are indebted to Capt. Hugh L. Keegan, MSC, Army Medical Service Graduate School, Walter Reed Medical Center, Washington, D.C., for taxonomic identification of the mite, *Myocoptes musculinus*.

[3] We wish to thank Dr. O. J. Grummitt, Western Reserve University, Cleveland, Ohio, and Mr. A. J. Gunderson, Sherwin-Williams Company, Cleveland, Ohio, for a generous supply of DMC, technical grade.

vals. This procedure maintained an effective miticidal concentration of DMC for newly-hatched larvae. On several occasions, the mice appeared to be "mite free" except for a few parasites clinging to the base of the eyelashes. For this reason, it was necessary to scrub the animals about the eyes and mouth with the DMC solution.

The mice probably ingest a considerable amount of the acaricide in cleaning themselves after DMC treatment. Peters studied oral toxicity of DMC in rats and mice. Mice (18 to 22 gms.) were given single doses of DMC in corn oil and others were given an aqueous suspension of DMC. A dose of DMC in corn oil, 250 mg./kg., was well-tolerated by mice. He found no mortality from a single dose of DMC in aqueous suspension of 500 mg./kg. Higher levels of DMC in corn oil and aqueous suspensions resulted in paralysis and death. Urinary incontinence, tremors, ataxia, and impairment of balance was observed in moribund animals, but not in survivors. Growing rats tolerated a diet containing 0.1 per cent DMC during a 10-week period. The oral toxicity of DMC for rats and mice was similar to that reported by Woodard *et al.* for DDT under similar conditions.

We observed that young mice acquire their infestation when 10 to 15 days of age. The mites are generally first seen on the whiskers around the nose and mouth. Thus, the host transfer is probably accomplished while the young are nursing. Four-week-old mice and 3 to 5-month-old breeding mice have been treated with DMC. Breeder mice were treated before mating and twice during pregnancy at 5-day intervals with no adverse effects upon the newborn litter.

In addition to DMC treatment of mite-infested mice, the following control measures should be carried out to successfully eradicate the *Myocoptes* parasite and maintain a "mite free" colony: 1) isolate mice to be treated in a separate room; 2) mouse-proof colony breeding room and experimental rooms against wild mice; 3) paint ceiling, walls, floor, and shelves with 0.2 per cent DMC in 50 per cent alcohol; 4) autoclave water bottles, feeders, cages, etc. These measures are necessary in order to prevent accidental mechanical transfer of the mites. Our breeding colony and experimental mice have remained "mite free" for the past 9 months.

SUMMARY.—1. A method is described for eradication of the Listrophorid mite, *Myocoptes musculinus*, from laboratory mice using the miticide di-(*p*-chlorophenyl) methylcarbinol (DMC). 2. Additional control measures for maintenance of a "mite free" mouse colony are reported.

LITERATURE CITED

Bergmann, E. and A. Bondi. 1931. Über die Reaktionsweisen des phosphorpentachlorids (II. Mitteil). Ber. deutsch. chem. Gesellsch. 64B: 1455.

Grummitt, O. J., A. Buck and E. Becker. 1945. 1,1-di-(*p*-chlorophenyl) ethane. Jour. Am. Chem. Soc. **67:** 2265.

Grummitt, O. J. 1950. Di-(*p*-chlorophenyl) methylcarbinol. Science **111:** 361.

Peters, L. 1949. Oral toxicity of a new miticide, di-(*p*-chlorophenyl) methylcarbinol. Proc. Soc. Exptl. Biol. and Med. **72:** 304.

Waters, H. A. and E. D. Witman. 1950. Cited by O. J. Grummitt. Science **111:** 361.

Woodard, G., A. Nelson and H. Calvery. 1944. Acute and subacute toxicity of DDT. (2,2-bis-(*p*-chlorophenyl)1,1,1-trichloroethane) to laboratory animals. Jour. Pharm. Expt. Therap. **82:** 152.

Control of Insects and Spider Mites on Cotton in 1952

M. T. YOUNG and R. C. GAINES, *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Calcium arsenate, various organic insecticides, and mixtures of these materials were tested at Tallulah, Louisiana, in 1952 for control of the boll weevil, *Anthonomus grandis* Boh., the bollworm, *Heliothis armigera* (Hbn.), other lepidopterous larvae, the cotton aphid, *Aphis gossypii* Glov., and the two-spotted spider mite, *Tetranychus bimaculatus* Harvey.

METHODS.—Five experiments were conducted in plots arranged in randomized blocks, with four replications of each treatment. Each plot was 12 rows wide and of sufficient length to cover about 0.1 acre. All insect and mite infestation and yield records were made on the four middle rows.

Boll weevil-injured squares were determined by examining 100 squares and bollworm-injured bolls by examining 100 bolls in each plot. Counts of aphids and spider mites were made by recording the number on 100 square inches of leaf area. One square inch was examined per leaf near the center on the underside of the fourth leaf from the top of the plant.

In experiments 1 and 5 and in the dust treatments in experiments 2, 3, and 4 all insecticides were applied with single-nozzle rotary hand dusters early in the morning. In experiments 2 and 3 various sprays, applied with a three-row (one nozzle per row) sprayer when the plants were dry, were compared with dusts and no treatment. In experiment 4, 3-5-40 (a mixture containing sufficient BHC to give 3 per cent of the gamma isomer plus 5 per cent of DDT plus 40 per cent of sulfur) alternated with calcium arsenate and a mixture of 2.5 per cent of aldrin plus 5 per cent of DDT were applied as dusts for insect control. Six acaricides were applied with the three-row sprayer late in August for control of the two-spotted spider mite on plots that had been treated with the aldrin-DDT mixture.

All the cotton was planted about April 20 and a good stand was obtained in each plot. The boll weevil was the most important insect, but a very hot dry summer gave considerable climatic control of this pest. Spider mites were not sufficiently numerous to cause damage in experiments 2 and 4 until late in August. Bollworm damage was light during the early part of the season but increased in August, causing considerable loss in some of the untreated plots. Cotton aphid infestations were very low.

RESULTS.—Experiment 1 (Table 1). Insecticides were applied as dusts on July 21, 25, 30, August 4, 8, 13, 18, and 22. The spider mite infestation was low and of little importance during the entire season. The aphid infestation was light, but was heaviest in the plots treated with 3-5-40 alternated with calcium arsenate, the heptachlor-DDT, and the aldrin-DDT dusts. The bollworm infestation was light. All the mixtures controlled this pest. Methyl parathion 2

[1] The authors were assisted in the field by G. L. Garrison, E. H. Fisher, R. G. Duncan, C. E. Powell, C. M. Swanson, and H. K. Watts.

Table 1.—Results obtained in Experiment 1.

Dusts (Figures in Per Cent)	Pounds per Acre	Per Cent Weevil-Punctured Squares		Aphids per Square Inch		Mites per Sq. Inch, Average 3 Counts Aug. 14–28	Per Cent Bollworm-Injured Bolls Aug. 28	Seed Cotton per Acre	
		First July 16	Average 6 Counts July 22–Aug. 12	Initial July 10	Average 6 Counts July 24–Aug. 28			Total (lbs.)	Gain Over Check
Untreated check	—	21	36	0.03	0.80	0.88	8	2461	—
3-5-40 alone	11	25	13	.01	.26	.21	2	2595	134
3-5-40 alternated with calcium arsenate	9	25	12	0	1.13	.25	3	2696	235
Toxaphene 20+sulfur 40	14	26	12	0	.35	.04	3	2743	282
DDT 5+sulfur 40+									
Aldrin 2.5	9	22	14	0	.63	.18	3	2747	286
Dieldrin 1.5	10	28	10	.01	.35	.13	0	3038	577
Heptachlor 2.5	12	20	9	0	.82	.13	1	2768	307
Toxaphene 15	13	29	9	0	.28	.01	1	2731	270
Methyl parathion 2+DDT 5	9	21	22	0	.07	.08	2	2659	198
Minimum significant difference at 5% level		—	4	—	.53	.34	3	—	

per cent plus DDT 5 per cent did not give satisfactory control of the boll weevil, although all the other insecticides did. The increased yields for the treated plots were small and nonsignificant, but were greatest on the plots treated with DDT 5 per cent plus sulfur 40 per cent plus either dieldrin 1.5 per cent or heptachlor 2.5 per cent. There were no significant differences among the yields.

Experiment 2 (Table 2). Insecticides were applied on July 18, 23, 28, August 1, 6, 11, 15, 20, and 25. The dusts and sprays gave satisfactory control of the boll weevil and the bollworm. 3-5-40 dust alternated with calcium arsenate, the toxaphene dust, and the heptachlor-DDT spray caused a greater build-up of cotton aphids than the remaining treatments. Sprays containing toxaphene alone and toxaphene plus DDT did not cause so great an increase of the two-spotted spider mites as the remaining sprays. A Systox spray was applied to the six center rows of each plot (checks included) on August 25 at the rate of 0.51 pound of technical material per acre. That application gave almost perfect control of cotton aphids and spider mites. Although the toxaphene spray caused light burning and some leaf shedding, the toxaphene-DDT spray caused severe burning of the cotton foliage on all applications, resulting in heavy shedding of leaves and a smaller increased yield than on plots receiving the remaining treatments. The increase in yields was greater on the toxaphene-dusted plots than on either of the sprayed ones. The greatest increased yields were on the plots treated with 3-5-40 alternated with calcium arsenate.

Experiment 3 (Table 3). Insecticides were applied on July 18, 23, 28, August 1, 6, 11, 15, and 20. All of them, whether applied as dusts or sprays, gave satisfactory control of the boll weevil, the cotton aphid, and the bollworm. EPN and Metacide sprays gave the best control of the two-spotted spider mites, and sprays containing dieldrin plus endrin or aldrin plus endrin caused the greatest build-up of this pest. The increased yields were small and nonsignificant, owing to a light boll weevil infestation caused by climatic control. The greatest increased yields were made on plots treated with the Metacide spray and 3-5-40 alternated with calcium arsenate.

Experiment 4 (Table 4). Insecticides were applied as dusts on July 21, 25, 30, August 4, 8, 13, 18, and 22. 3-5-40 alternated with calcium arsenate and no treatment were compared with aldrin 2.5 per cent plus DDT 5 per cent, which was used in order to build up populations of two-spotted spider mites for testing parathion, Metacide, Aramite, TEPP,

Table 2.—Results obtained in Experiment 2.

Dusts or Sprays	Pounds Technical Material per Acre	Per Cent Weevil-Punctured Squares		Aphids per Square Inch		Mites per Sq. Inch	Per Cent Boll-worm-Injured Bolls Aug. 28	Pounds Seed Cotton per Acre	
		Initial, July 16	Average 7 Counts July 21–Aug. 18	Initial July 10	Average 5 Counts July 24–Aug. 21	Average, 2 Counts Aug. 14 and 19[1]		Total	Gain Over Check
Check	—	21	46	0	1.09	1.11	19	2012	—
Dusts (per cent):									
3-5-40 alternated with calcium arsenate	0.3–.5–4	26	18	.02	2.00	.35	4	2797	785
Toxaphene 20	2.6	28	12	.01	.82	.95	4	2729	717
Sprays (pounds per gallon):									
BHC gamma 0.6+ DDT 1	.33– .55	33	11	0	.05	1.49	1	2706	694
Aldrin 2+DDT 2	.27– .54	32	9	0	.35	1.71	0	2620	608
Dieldrin 1.5+DDT 2	.17– .58	30	9	0	.19	.97	2	2746	734
Toxaphene 4+DDT 2	2.65–1.33	26	6	0	.04	.13	0	2247	235
Toxaphene 6	2.78	26	11	.01	.36	.48	6	2515	503
Heptachlor 1+DDT 2	.25– .50	27	9	0	.94	1.20	3	2706	694
BHC gamma 0.9+ DDT 1.5	.32– .53	28	11	0	.04	1.07	1	2776	764
Minimum significant difference at 5% level		—	2	—	.57	.88	5	—	

[1] No aphids or mites found in two counts made on August 28 and September 4.

Table 3.—Results obtained in Experiment 3.

Dusts or Sprays	Pounds Technical Material per Acre	Per Cent Weevil-Punctured Squares		Aphids per Sq. Inch, Average, 6 Counts July 24–Aug. 27	Mites per Sq. Inch Average, 3 Counts Aug. 14–27	Per Cent Bollworm-Injured Bolls on Aug. 27	Pounds Seed Cotton per Acre	
		Initial July 17	Average 6 Counts July 21–Aug. 12				Total	Gain Over Check
Check	—	20	28	0.18	1.33	16	2253	—
Dusts (per cent):								
3-5-40 alternated with calcium arsenate	.3–.5–4	26	11	.07	.36	2	2565	312
Toxaphene 20+sulfur 40	2.60–5.20	26	11	.08	.03	3	2495	242
Sprays (pounds per gallon):								
Endrin 1.6	.22	24	10	.01	.56	2	2515	262
Aldrin 1.25+endrin 1.00	.123– .10	24	9	.01	.95	2	2444	191
Dieldrin 1.00+endrin 1.00	.10– .10	18	9	.01	1.49	2	2374	121
EPN 4+DDT 2	.71– .47	16	9	.01	.01	2	2414	161
Metacide 4	.67	25	14	.01	.01	4	2636	383
Minimum significant difference at 5% level		—	5	.06	.96	5	—	

Table 4.—Results obtained in Experiment 4.

Dusts or Sprays	Pounds Insecticide per Acre[1]	Per Cent Weevil-Punctured Squares		Aphids per Square Inch		Mites per Square Inch on—			Per Cent Reduction from Aug. 19 to 27	Per Cent Increase from Aug. 19 to Sept. 4	Per Cent of Bollworm-Injured Bolls on Aug. 27	Pounds Seed Cotton per Acre	
		Initial on July 17	Average 6 Counts July 22–Aug. 12	Average 5 Counts July 24–Aug. 21	Per Cent Reduction from Aug. 21 to 27	August 19	August 27	Sept. 4				Total	Gain Over Check
Dusts (per cent; 8 treatments)													
Untreated check	—	23	45	0.30	92	3.36	1.79	11.00	47	227	15	2203	—
3-5-40 alternated with calcium arsenate	11	25	17	.62	22	.90	.82	2.96	9	229	4	2615	412
Aldrin 2.5+DDT 5	10												
Sprays (pounds per gallon; 1 treatment, each on aldrin-DDT dust plot)													
Parathion 2	0.25	17	19	.18	87	2.94	.78	11.18	73	280	4	2475	272
Metacide 4	.76	27	19	.27	97	3.96	.58	13.96	85	253	4	2515	312
Aramite 2.4	.68	27	18	.27	91	5.21	.82	14.97	84	187	2	2545	342
TEPP 3.2	.28	25	18	.21	88	3.71	1.67	13.86	55	274	4	2666	463
Systox 4	.59	25	15	.14	100	4.09	.24	.84	94	79[2]	4	2716	513
R-242-2	.98	27	18	.19	98	3.15	1.07	7.44	66	136	3	2505	302
Minimum significant difference at 5% level		—	5	.25		—	—	5.12			6	—	

[1] Sprays: Pounds of technical material per acre.
[2] Per cent reduction.

Table 5.—Results obtained in Experiment 5.

Dusts (Figures in Per Cent)	Pounds per Acre	Per Cent Weevil-Punctured Squares		Aphids per Square Inch, Average, 5 Counts July 24–Aug. 27	Mites per Square Inch, Average 4 Counts Aug. 7–27	Per Cent of Bollworm-Injured Bolls Aug. 27	Pounds of Seed Cotton per Acre	
		Initial Infestation July 17	Average of 6 Counts July 22–Aug. 12				Total	Gain Over Check
Untreated check	—	28	55	0.11	3.10	14	2138	—
3-5-40 alternated with calcium arsenate	10	27	17	.41	.69	5	2706	515
BHC gamma 6+DDT 10	5	31	20	.08	3.42	1	2655	464
BHC gamma 3+DDT 5 + special oil	11	28	12	.03	4.51	1	2712	521
+Aramite 4	10	30	16	.07	.22	2	2759	568
+parathion 1	8	29	17	.02	.20	2	2638	447
+Metacide 1	9	28	17	.02	1.96	2	2716	525
+Aramite 2	12	31	14	.07	.40	1	2855	664
Metacide 2	10	26	14	.01	1.86	6	2895	704
BHC gamma 3+DDT 5	11	35	15	.01	2.91	2	2615	424
3-5-40	11	26	23	.12	.43	7	2768	577
Untreated check	—	35	55	.12	2.51	13	2244	—
Minimum significant difference at 5% level		—	6	.16	1.23	6	335	

Systox, and R-242. These acaricides were applied as sprays on August 22. A light shower fell soon after the spray applications were completed. The dust treatments all gave satisfactory control of the boll weevil, the bollworm, and the cotton aphid. The spider mite count made on August 27 showed that all the acaricides reduced the population of spider mites. The reduction was greatest where Systox was used. The count made on September 4 revealed that there was a rapid build-up of spider mites in all the sprayed plots except where Systox was used, which still showed a reduction of 79 per cent. The greatest increased yield was on the plots dusted with aldrin-DDT and sprayed with Systox.

Experiment 5 (Table 5). Insecticides were applied as dusts on July 18, 23, 28, August 1, 6, 11, 15, and 20. Boll weevil infestations were significantly lower in all treatments than in the untreated checks. Aphid infestations were significantly lower in all the treatments than where 3-5-40 was alternated with calcium arsenate. Metacide gave good control of aphids and of the boll weevil but poor control of two-spotted spider mites. Dusts with BHC gamma 6 per cent plus DDT 10 per cent, BHC gamma 3 per cent plus DDT 5 per cent plus special oil, or BHC gamma 3 per cent plus DDT 5 per cent also gave poor control of two-spotted spider mites. All treatments gave good control of the bollworm. The greatest increase in yield was made on plots receiving the Metacide 2 per cent. All insecticide treatments showed a significant increase in yield over the checks, but the differences between the various insecticides were not significant.

A Rapid Method for Estimating Aerial Spray Deposits

J. M. DAVIS, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*, and K. R. ELLIOTT, *Canada Dept. Agr., Division of Forest Biology*

In applying airplane sprays for insect control or for experimental purposes, it is essential to determine the dispersal and deposition of the spray material. This is usually accomplished by placing indicating cards or recovery plates along lines laid at right angles to the line of flight of the aircraft to receive samples of the spray as it falls. For fast visual assessment, heavy pressed paper cards, known as jump cards, and sensitized paper have been used. These devices require the addition of a tracer or a chemical activator to the spray, and the results are often of questionable accuracy. For more accurate information, plates of glass or metal are used to capture the falling spray, thus permitting standard chemical or colorimetric analysis of deposits.

The chief disadvantages of these methods are the weight and fragility of the material, and the cost, handling hazards, and the need for laboratory facilities. When measurements of droplet size are required, glass plates or microscope slides coated with magnesium oxide, carbon, oleophobic material, or other substance are generally used. After they have been sprayed, one is able to determine the size of the drops by measuring them or their imprints. All these materials are affected by rain or dew and many by sunlight. This necessitates their distribution immediately before and prompt collection after spraying, which materially reduce personnel efficiency. These methods are time consuming and physically impractical in the assessment of large areas.

Airplane spraying on both small and large forested areas in Canada and the United States for the control of many different insect pests has emphasized the need for a method of assessment that is not subject to the disadvantages outlined above. In a study conducted at Beltsville, Maryland, the Bureau of Entomology and Plant Quarantine, in cooperation with the Canada Department of Agriculture, has developed a dyed paper which indicates the degree of atomization and the quantity of deposit falling on it and is sensitive to almost any oil-base solution.

The main problem in this study was to find a surface, and a material that could be placed on it, which would show where contact was made by the spray without the spray spots being confused with the texture of either the surface or the material. Numerous materials and solvents were therefore tested on about 30 types of paper and plastic surfaces. Criteria for selection were maximum contrast between spray spots and background and minimum confusion from texture. Contrast was found to vary with the material, and also with the volatility of the solvent. Background confusion was confined to papers and found to be a matter of paper quality.

The final selection was a paper that before treatment is white, glossy, of medium weight and even texture, with a clay-bearing calender roll finish.[1] It is treated with an oil-soluble red dye in such a way that the greater part of the dye is left adhering to the surface.

When a spray droplet strikes the surface of the paper, it appears to dissolve and carry most of the dye to its perimeter. This results in a circular pinkish spot outlined by a dark ring of dye. Over a considerable range of drop sizes the ratio of the diameter of the ring to that of the droplet producing it is fairly constant, from 1:6 to 1:7 depending on characteristics of the spray used. Because this ratio is large, small droplets are readily visible, and because of its consistency, the method is usable for the rough determination of droplet sizes.

The paper is not costly and is easy to prepare in card form. The cards are convenient to carry and distribute, can be left exposed in the field for several days if necessary, and the deposits can be readily evaluated. The cards are not affected by rain or dew (in fact, they can be used while wet unless the water forms a film on them), and may be retained as a permanent record. This method does not require the addition of extra material to the spray. The cards not only indicate the adequacy of coverage, but are also useful for determining the relationship between dosage and mortality.

Prolonged exposure to sunlight in the presence of moisture may cause some fading of the dye, but sufficient dye usually remains to indicate spray drops, though they may appear red on a pink background instead of the normal pink on a red background.

The indicated deposit may be expected to show some reduction due to evaporation. The amount of reduction will be somewhat proportional to the vapor pressure of the insecticide at the ambient temperature and to the time required for the spray to settle, and inversely proportional to the square of the drop size. The reduction is thought to be negligible with the oils used in most airplane sprays, but would

[1] Some of the papers having the proper finish are Printflex Cover, Process Plate, and Richfold, which are available in various sizes and weights from Mead Paper Corporation, Chilicothe, Ohio, and Kingsport, Tennessee.

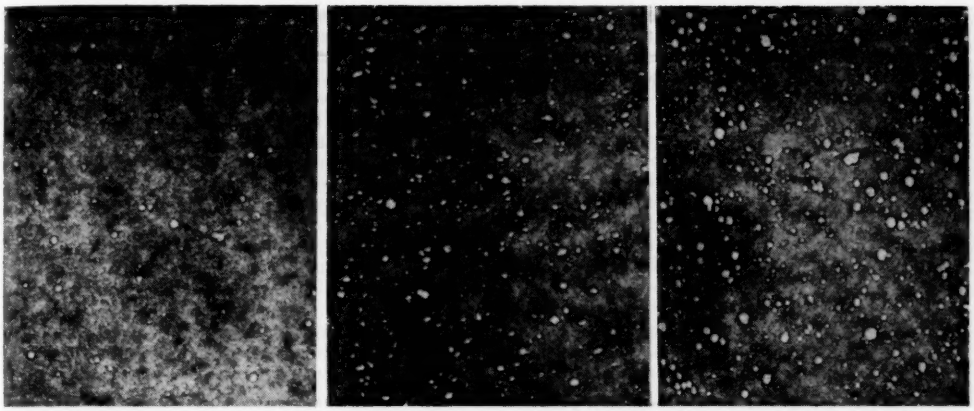


FIG. 1.—Standard dosages of 0.20, 0.50, and 1.00 gallon per acre on oil-sensitive cards.

be greater when more volatile solvents such as xylene or trichloroethylene are used.

These cards can be prepared by dipping the paper as rapidly as possible in a solution of 1 gram of du Pont oil red dye in 200 ml. of acetone. They can be prepared also by applying the dye solution with a hand roller or brush. The acetone evaporates quickly, leaving the dye on the surface of the cards, which are then ready for use.

The size of the card is not critical, from 4 by 5 to 5 by 8 inches having been used. To keep the cards in the desired position or location, they may be fastened to anything convenient with thumb tacks, staples from a stapling machine, adhesive tape, or other means. After the cards have been exposed to falling spray, deposits can be evaluated visually to an accuracy of about 5 per cent by comparing them with known standards, *i.e.*, previously prepared cards bearing known amounts of deposit.

Since our cards were to be used to evaluate airplane spray deposits, we used airplane spray in making up the standards. These standards were made up as follows: Sampling stations, each consisting of a number of cards interspersed closely with aluminum plates, were placed in a line at right angles to the line of flight of the airplane. After the spraying the aluminum plates were collected and the deposits analyzed chemically. The deposit on the aluminum plates at any station was assumed to be the same as that on the adjacent cards. Deposits equivalent to dosages ranging from zero to about 1 gallon per acre were obtained at the various stations.

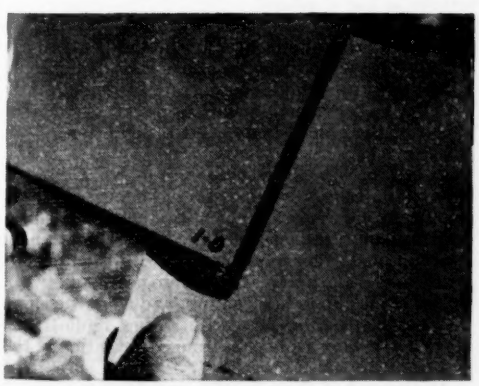


FIG. 2.—Estimating by comparing a spray deposit with a known deposit of 1 gallon per acre. Photograph by D. C. Anderson, Forest Insect Laboratory, Sault Ste. Marie, Ontario.

Sets consisting of one card each representing the dosages 0.05, 0.10, 0.20, 0.50, 0.75, and 1.00 gallon per acre have been assembled into booklets for field use. Similar sets are kept unassembled for use in the laboratory; these cards are arranged in ascending order and the unknowns compared with them for assessment. Figure 1 shows three of these standards. In figure 2 a field deposit is being compared with the standard for 1.00 gallon per acre in the booklet. It is fairly obvious that this field deposit is less than the standard shown; it was evaluated at 0.9 gallon per acre after being compared further with the 0.75 gallon standard.

When unknown deposits have been assessed by this method by different people, the results have been found to be fairly uniform. On one project, for example, of 8000 samples assessed by four men only 0.8 per cent were found to be in variance when rechecked by the supervisor. Thus it appears that differences due to personnel are of minor importance. For greatest accuracy the drop size on the standard should match that of the unknown. Further work is in progress to develop standards that will apply to all drop spectra and can be reproduced by photographic or printing methods.

In a large-scale control operation in New Brunswick in 1952, about 17,000 of these cards were left exposed in the forest for 10 to 30 days. Both sides of the cards were used, one for the initial spray and the other, where required, for respray deposits. Although extremely wet weather hampered the operation, it did not harm the cards. Some dye fading was encountered, the degree depending on the exposure to simultaneous sunlight and moisture, but this was of no serious consequence. Four per cent of the cards were damaged by animals, but sufficient surface was left intact to allow assessment of the deposit. Similar observations have been made on other control operations and in experimental work in different parts of the United States.

The chief advantages of this method of visual assessment are the ease of handling and the rapidity of evaluation. About 300 samples can be assessed per man hour in the laboratory. The method is ideal for control projects and with further refinement of

Table 1.—Per cent mortalities of house flies in one day caused by scabrin stored for various periods. (Means of four replicates.)

Storage Sample	Freshly Prepared	1 Week	2 Weeks	7 Weeks	11 Weeks	28 Weeks	50 Weeks	79 Weeks
Scabrin alone[1]	67	40	55	23	60	60	70	83
Scabrin plus—[2]								
2,2′ Methylenebis-(4-methyl-6-*tert*-butylphenol)	85	52	89	71	70	57	76	80
Di-*tert*-butyl-*p*-cresol	79	50	86	52	66	37	46	54
Mono-*tert*-butyl-*m*-cresol	81	48	93	62	82	74	77	90
Phenol S (mixture of isopropyl cresols)	80	48	82	67	72	59	68	72
Hydroquinone	84	41	65	56	67	57	71	83
Difference required for significance at 19:1 odds	9	15	19	15	17	26	18	10

[1] A freshly prepared spray used in each of the last four series.
[2] Antioxidants alone caused negligible mortalities.

standards may be sufficiently accurate for use in experimental spraying.

Literature Cited

Elliott, Kenneth R. 1952. A new method of assessing aerial spray deposits. Canada Dept. Agr., Science Serv., Div. Forest Biology, Bimonthly Progress Rpt. 8(2): 1.

The Stabilization of Scabrin Oil Sprays

Norman Mitlin and W. A. Gersdorff *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In a previous paper (Gersdorff & Mitlin 1952) it was reported that kerosene sprays containing the new insecticide scabrin alone, at least those at relatively high concentrations, appeared to lose toxicity to the house fly on standing. A study was undertaken to determine whether such sprays could be stabilized by the use of antioxidants. In work with pyrethrins it has been reported that certain compounds of a phenolic nature were effective antioxidants for this toxicant (Yates 1934; Voorhees 1935; Trusler 1940; Bushland *et al.* 1945). Therefore, compounds of this type were selected for examination as stabilizers for scabrin.

Materials.—Purified scabrin was incorporated in refined kerosene sprays together with one of the following materials:[1] 2,2′-methylenebis-(4-methyl-6-*tert* butylphenol), known as antioxidant 2246; di-*tert* butyl-*p*-cresol; mono-*tert*-butyl-*m*-cresol; a mixture of isopropyl cresols, a byproduct of thymol manufacture, known as Phenol S; and hydroquinone. Each of the first four compounds was used in the scabrin solution at the rate of 1 mg. per milliliter. Hydroquinone, being less soluble than the other materials, was used at saturation. Also included in this study was one spray containing scabrin alone. In all tests scabrin was used at 2 mg. per milliliter.

In addition, the antioxidants alone were incorporated in refined kerosene sprays at the same concentrations as above to determine whether such sprays were toxic.

All sprays were held in amber bottles in a cupboard at room temperature for the duration of the study.

Procedure.—The tests were made by the Campbell turntable method on adult laboratory-reared house flies, *Musca domestica* L., about 2 days old. Approximately 100 flies were used in each test. The sprays were tested as a series in 1 day—when freshly prepared, then weekly for the first 3 weeks, and then at progressively longer intervals. Each series of tests included four replicates for each spray.

A fresh scabrin spray could not be included in the first four series, since the number of tests in the first series was the maximum number that could be made at one time. After it had been decided that the loss in toxicity of the scabrin spray was definite, a freshly prepared spray was substituted for it in each series.

The sprays containing the antioxidants alone were tested twice.

Results.—The mortality data are summarized in table 1. An analysis of variance was run on the mortalities in each series to determine whether any differences found in mortality for a particular mixture, when compared with the scabrin spray, were significant. The amount required for significance is shown in table 1.

The antioxidants alone were relatively nontoxic at the concentrations used when tested with pyrethrin as the standard.

Discussion.—In the first tests with freshly prepared spray the difference in mortalities between the scabrin spray and the mixtures was significant. Either scabrin at nigh concentrations tends to lose toxicity, as previously noted (Gersdorff and Mitlin 1952), or the antioxidants exert a slight synergistic effect.

After 1 week no differences were shown. However, tests made after 2 weeks' storage again showed a significant difference in mortalities between scabrin and the mixtures, except for the one containing hydroquinone. This inconsistency with the previous series may result from the heterogeneity between the different populations of flies, and from the effort to show small differences with so few replications. However, it may also result from depreciation of the scabrin spray after 2 weeks.

At the end of 7 weeks the scabrin alone caused markedly lower mortality than the mixtures. In the first three series the mixtures did not differ materially from one another. However, in the next three, that is, in the interval of 7 to 28 weeks'

[1] Supplied by Martin Jacobson, Bureau of Entomology and Plant Quarantine.

storage, the results indicated depreciation in the spray containing di-*tert*-butyl-*p*-cresol. In the last two series, that is, after 50 and 79 weeks' storage, this depreciation was definitely shown for this spray. All the other mixtures in the four series made after 7 weeks maintained their high level of effectiveness and were equal to fresh scabrin within experimental error. It is probable there was no synergism in these mixtures as first indicated. To decide this, tests designed specifically to determine synergism would be necessary.

CONCLUSIONS.—The compounds 2,2′-methylene-bis-(4-methyl-6-*tert*-butylphenol) (antioxidant 2246), mono-*tert*-butyl-*m*-cresol, Phenol S (a mixture of isopropyl cresols, a byproduct of thymol manufacture), and hydroquinone effectively stabilized scabrin in kerosene sprays for a period of 1½ years. Di-*tert*-butyl-*p*-cresol apparently was effective for a shorter period. Depreciation of its mixture was demonstrated statistically after 11 weeks.

LITERATURE CITED

Bushland, R. C., Milton S. Schechter, Howard A. Jones, and E. F. Knipling. 1945. Antioxidants for pyrethrum powders. Soap and Sanit. Chem. **21**(11): 119, 121.

Gersdorff, W. A. and Norman Mitlin. 1952. Relative toxicity to house flies of scabrin and its mixtures with some pyrethrum synergists. JOUR. ECON. ENT. **45**(3): 519.

Trusler, R. B. 1940. Prolonging toxicity of pyrethrum insect sprays. Soap and Sanit. Chem. **16**(1): 115, 117, 119.

Voorhees, V. 1945. Light stable pyrethrum extract. U. S. Patent 2,011,428, August 13.

Yates, W. J. 1934. Stabilizers for pyrethrum oil sprays. Canadian Patent 343,209, July 17.

Toxicity of Vapors of Four Chlorinated Hydrocarbon Insecticides to Resistant House Flies[1,2]

H. G. WILSON, J. B. GAHAN, and W. C. MCDUFFIE, *U. S. D. A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

DDT and other chlorinated hydrocarbon insecticides have been used extensively for the control of house flies, *Musca domestica* L., throughout central Florida since World War II. All these insecticides were highly effective for several years, but at present none of them will provide effective control of house flies either as residual or as space sprays. Laboratory tests of the flies from various dairies in comparison with nonresistant laboratory-colony flies have confirmed the fact that natural populations are resistant to residual and space sprays of all the chlorinated hydrocarbon insecticides, which accounts for their ineffectiveness in control operations (Gilbert *et al.* 1952).

Since lindane, chlordane, dieldrin, and aldrin are fumigants as well as contact insecticides, it was thought that this characteristic might be utilized to control house flies despite their resistance to residual and space sprays of these insecticides. Information on the fumigating action of insecticides is of special significance since a number of lindane and DDT vaporizers have recently appeared on the market. A series of tests was therefore conducted in 1952 to determine whether flies resistant to contact with these insecticides were also resistant to their fumigating action.

One nonresistant and three resistant strains of flies were included in the tests. Two of the resistant strains were laboratory-reared, and the other consisted of collections of wild flies from a local dairy (Ballard). The dairy had been treated frequently with residual and space sprays of lindane during the summer of 1951, but the treatments were relatively ineffective. Late-season applications of DDT, methoxychlor, CS-708, and Lauseto neu (chloromethyl *p*-chlorophenyl sulfone) were completely ineffective in this dairy. Laboratory residue tests showed these flies to be highly resistant to lindane and DDT (table 1).

One of the laboratory resistant colonies (Orlando No. 1) was developed from the nonresistant laboratory colony and has been maintained since January 1946. Each generation of this colony has been sprayed with DDT to build up and maintain a high level of resistance. At the time of the tests reported herein (112th generation) this colony was so resistant that more than 1500 times as much DDT was required to kill 40 per cent of the adults as was required to kill 90 to 95 per cent of the nonresistant laboratory strain. This colony has been exposed only to DDT, but has acquired some cross-resistance to lindane, dieldrin, and chlordane.

The other laboratory resistant colony (LDD) was started in 1951 with flies collected from two local dairies where control could not be obtained with DDT, dieldrin, or lindane. Since that time resistance to these chemicals has been maintained by continuously exposing panels treated with 5 mg. each of lindane and dieldrin and 12.5 mg. of DDT per square foot in the adult-holding cages. Freshly treated panels are introduced every week. Laboratory residue tests showed this colony to be considerably more resistant to lindane and dieldrin than the Orlando No. 1 or the regular colony but much less resistant to DDT than the No. 1 colony (table 1).

The fumigation tests were conducted in a plywood box 32 inches square, fitted with a top in which were 49 round holes slightly larger than the diameter of a standard cylindrical screen-wire cage. Each hole was fitted with a removable cover with a short length of wire attached for suspending the cage in the box without contacting the inside surfaces. A piece of cheesecloth impregnated with 12 grams of the toxicant was placed inside the box over a coarse wire screen about a foot square. With all openings in the top of the box closed, a 6-inch fan was allowed to blow over the treated cloth for 15 hours to assure a maximum concentration of vapor in the air. The fan was turned off 1 hour before the exposures were scheduled to allow any solid particles to settle. Caged flies were exposed inside the box at 80° F. for periods ranging from 15 minutes to 24 hours, after which they were removed from the box, given food and water, and held at the same temperature for the completion of the 24-hour period. Each test was repeated on another day. Results of the tests are given in table 1.

The degree of resistance of the various colonies to the vapors of the four insecticides was fairly closely correlated with their resistance to residues of lindane. The Ballard flies were the most resistant to lindane residues and also to lindane vapors. They

[1] This work was conducted at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine under funds alloted by the Department of the Army to the Bureau.

[2] The writers wish to thank T. B. Hester for his assistance in conducting the routine duties connected with this research.

Table 1.—Toxicity of vapors of chlordane, lindane, dieldrin, and aldrin to resistant and nonresistant strains of house flies.

Colony	Per Cent Mortality 24 Hours After Beginning of the Indicated Exposure Period							LT-50 in Minutes	
	15 Minutes	30 Minutes	1 Hour	2 Hours	4 Hours	8 Hours	24 Hours	Vapor Tests	Residue Tests[1]
				Chlordane					
Nonresistant (regular) strain	24	54	62	84	96	98	100	33	—
Resistant strains:									
Orlando No. 1	6	20	42	66	98	98	100	69	—
LDD	2	4	4	8	38	36	100	347	—
Ballard	6	4	8	6	24	34	100	380	—
				Lindane					
Nonresistant (regular) strain	28	76	78	94	100	100	100	25	10.9
Resistant strains:									
Orlando No. 1	2	10	58	82	100	100	100	58	16.4
LDD	4	4	14	24	48	66	100	173	65.6
Ballard	8	16	16	20	32	38	94	316	229.3
				Dieldrin					
Nonresistant (regular) strain	20	58	66	78	80	94	98	40	<1
Resistant strains:									
Orlando No. 1	4	4	8	42	94	100	100	110	9.1
LDD	6	12	8	8	24	30	86	550	>120
Ballard	12	12	10	14	18	30	86	550	—
				Aldrin					
Nonresistant (regular) strain	80	84	88	98	100	100	100	<15	—
Resistant strains:									
Orlando No. 1	18	66	100	100	100	100	100	23	—
LDD	2	12	30	32	36	88	98	158	—
Ballard	12	20	46	38	60	92	100	96	—
				DDT					
Nonresistant (regular) strain	—	—	—	—	—	—	—	—	9.0
Resistant strains:									
Orlando No. 1	—	—	—	—	—	—	—	—	ca.1,440
LDD	—	—	—	—	—	—	—	—	>240
Ballard	—	—	—	—	—	—	—	—	343.4

[1] LT-50's as residues are included merely as a general indication of the relative resistance of the different colonies.

were slightly more resistant than flies of the LDD colony to vapors of chlordane and slightly less resistant to vapors of aldrin, but there was no difference in their resistance to vapors of dieldrin. Ballard and LDD flies were both more resistant to vapors of all four insecticides as well as to lindane residues than were regular flies or flies of the Orlando No. 1 colony.

Flies of the Orlando No. 1 colony exhibited slightly more resistance to residues of lindane and dieldrin than did the regular colony, and also showed slightly greater resistance to the vapors of the four insecticides. It would appear, therefore, that a high degree of resistance to DDT alone had very little deterrent effect on the toxicity of vapors of lindane, chlordane, dieldrin, or aldrin.

The vapors of aldrin appeared to be slightly more toxic to all four strains of flies than were those of lindane, chlordane, or dieldrin. However, an 8-hour exposure to aldrin vapor was insufficient to kill all the LDD and Ballard flies, and an exposure of 4 hours was necessary to give 100 per cent mortality of regular-colony flies. Dieldrin and chlordane failed to cause total mortality of the LDD, Ballard, and regular flies after 8 hours, but gave complete or almost complete kills of those of the Orlando No. 1 colony. Dieldrin also failed to cause 100 per cent kill of the same three colonies in 24-hour exposures, but chlordane was completely effective against all colonies at this exposure.

Exposure times required to cause complete mortality were too long to justify the conclusion that these materials could be used successfully as fumigants against resistant or nonresistant flies in buildings where flies can readily enter or leave.

Summary.—Laboratory studies in 1952 with nonresistant house flies (*Musca domestica* L.), flies resistant to DDT only, and flies resistant to several chlorinated hydrocarbon insecticides showed that their resistance to vapors of lindane, chlordane, dieldrin, and aldrin was closely correlated with their resistance to residues of lindane, less closely with resistance to residues of DDT. The exposure times required to cause mortality were too long to justify the conclusion that these materials could be used as vapors to control resistant flies.

Literature Cited

Gilbert, I. H., M. D. Couch, and W. C. McDuffie. 1953. Development of resistance to insecticides in natural populations of house flies. Jour. Econ. Ent. 46(1): 48–50.

Sensitivity to DDT of Nerve Ganglia of Susceptible and Resistant House Flies

John J. Pratt, Jr.,[1] and Frank H. Babers,
U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine, Beltsville, Maryland

House flies, *Musca domestica* L., that are resistant to DDT can metabolize greater quantities of DDT in a given time than can susceptible flies. The principal metabolic product is DDE, the ethylene deriva-

[1] Present address: Chemicals and Plastics Branch, Research and Development Division, Office of the Quartermaster General, Washington, D. C.

tive of DDT, which is much less toxic to house flies. There is disagreement in the literature as to whether the greater ability of resistant flies to metabolize DDT is a cause or an effect of resistance (Chadwick 1952). A significant fact against metabolism as the cause of resistance is that the tissues of resistant flies showing no symptoms of poisoning may contain quantities of DDT many times greater than those that would be lethal to susceptible flies (Perry & Hoskins 1951; Winteringham *et al.* 1951). It is probable, then, that some mechanism inhibits the poisoning of resistant flies by DDT, and that differences in ability to metabolize may be associated with the degree to which the fly is poisoned. No data are available concerning the comparative abilities of susceptible and resistant flies to metabolize DDT when in the same stage of poisoning.

Since DDT can be present in the tissues of resistant flies, presumably at the sites of poisoning action, and yet not poison the flies, it is of interest to investigate the comparative susceptibility to DDT poisoning of nerve tissue of susceptible and resistant flies.

Adult female house flies 3 days old were sealed to a block of beeswax ventral side up, under carbon dioxide anesthesia, and five legs removed, a metathoracic leg being left intact. The integument was cut transversely anterior to the metathoracic legs, with care not to sever the nerve to the intact leg, then anteriorly along each side of the thorax. The integument was then carefully dissected away from underlying tissues in order to expose the fused thoracic ganglion. To expose the ganglion completely, it was necessary to free its posterior end from a surrounding apodeme. The head of the fly was usually removed for convenience of manipulation, but failure to sever the brain had no obvious effect on the gross response used as a criterion of poisoning. Preparations remained in good condition for several hours when kept in a moist chamber, particularly if a small quantity of Hobson's saline (Hobson, 1928) was applied immediately after dissection.

The ganglion was poisoned by applying a DDT solution directly to its surface, and tremoring in the attached leg was used as the criterion of poisoning. Since large quantities of DDT were required to cause sufficient poisoning of ganglionic tissue to produce leg tremors within a short time after application, the necessity of containing the DDT in as small a quantity of liquid as possible presented difficulties in selecting a solvent. Solutions of DDT in corn oil were unsatisfactory, because poisoning action was slow and the tremoring leg frequently became contaminated with the solution. It is of interest to note that leg tremors produced by corn oil solutions of DDT decreased in intensity and occasionally ceased when the solution was washed from the ganglion with saline.

The most satisfactory preparation of DDT was an emulsion made from a stock solution containing 10 per cent each of DDT and Triton X-100 in Cellosolve. Immediately before use an emulsion was prepared by delivering the required amount of DDT solution into Hobson's saline under vigorous agitation in a mechanical blender. Emulsions containing up to 1 microgram of DDT per cubic millimeter remained stable for two hours or longer. An emulsion without the DDT, applied to the ganglion, caused no activity in the attached leg. One cubic millimeter of emulsion, the maximum amount that could be applied without apparent spreading to other tissues, was delivered from a micrometer-driven syringe directly onto the surface of the ganglion. Although the DDT emulsion was applied to the ganglion, the possibility of its site of action being other exposed nerve tissue is not excluded.

In the first series of experiments 0.57 microgram of DDT was applied to the ganglion. The quantity of DDT was later increased to 1.14 micrograms in order to obtain a poisoning response in all the susceptible flies within 5 minutes. Beginning 5 minutes after the poison was applied, the number of flies showing tremors in any segment of the leg was recorded at 10-minute intervals up to 60 minutes at the 0.57-microgram dosage level and 120 minutes at the 1.14-microgram level. Five susceptible and five resistant flies were observed in each experiment (Table 1).

Table 1.—Duration of leg tremors after application of DDT to the compound thoracic ganglion of house flies. Five susceptible and 5 resistant flies in each test.

Micrograms of DDT Applied	Period of Observations (Minutes)	Ratio of Number Tremoring at 5 Minutes to Number Tremoring at 60 or 120 Minutes	
		Susceptible	Resistant
0.57	60	4/5	2/0
		4/2	3/0
		4/4	4/1
		5/4	3/1
		5/4	4/2
		Total 22/19	16/4
1.14	120	5/5	5/3
		5/4	1/0
		5/5	3/1
		Total 15/14	9/4

It is obvious from the data in table 1 that (1) symptoms of poisoning appeared within 5 minutes after treatment in more susceptible than resistant flies, and (2) fewer resistant than susceptible flies had poisoning symptoms when observed at a given time after treatment. The observations suggest that ganglionic tissue of resistant flies is not as susceptible to DDT poisoning as that of susceptible flies; and that ganglionic tissue of resistant flies can recover from DDT poisoning more rapidly than can that of susceptible flies.

It is difficult to correlate the theory of detoxification of DDT to DDE as the cause of resistance with the first observation, since it is improbable that the DDT would be detoxified so rapidly as to prevent the appearance of symptoms after direct application to the ganglion. In no case, once tremors began, did they cease before the start of the selected observation period 5 minutes after the application of the toxicant. This would also rule out the possibility that the metabolic product DDE might serve to block the action of DDT. The more rapid recovery of the resistant flies is probably due to detoxification of the DDT, but does not necessarily indicate a faster rate of detoxification in resistant

flies. It is probable that the dosage threshold for poisoning by DDT is higher in resistant than in susceptible flies and that the threshold had not been reached in those flies that showed no symptoms at 5 minutes. In poisoned flies detoxification would result in cessation of symptoms sooner in resistant than in susceptible individuals.

LITERATURE CITED

Chadwick, Leigh E. 1952. The current status of physiological studies on DDT resistance. Am. Jour. Trop. Med. **1**: 404–11.

Hobson, A. D. 1928. Saline for insect tissue. Brit. Jour. Expt. Biol. **5**: 385–92.

Perry, A. S., and W. M. Hoskins. 1951. Detoxification of DDT as a factor in the resistance of house flies. JOUR. ECON. ENT. **44**: 850–7.

Winteringham, F. P. W., Patricia M., Loveday, and A. Harrison. 1951. Resistance of houseflies to DDT. Nature (London) **167**: 106–7.

The Toxicity of Aldrin, Dieldrin, and Toxaphene to Rabbits by Skin Absorption

BARBARA L. JOHNSTON and W. G. EDEN
Alabama Polytechnic Institute, Auburn

Aldrin, dieldrin, and toxaphene are widely used as insecticides for the control of cotton insects in Alabama. There has been considerable inquiry from applicators as to which of the compounds was the safest to handle. This concern about the relative toxicities of the insecticides prompted research on their toxicities by skin absorption.

Several investigators have reported on the toxicity of aldrin to warm-blooded animals. Lehman (1949) stated that aldrin was readily absorbed through the skin and was the most toxic of all insecticides from that standpoint. He also reported the acute oral dose of aldrin to lie between 30 and 80 mg./kg. Kitselman *et al.* (1949) administered aldrin in edible oil to albino rats and found the acute LD-50 to be 40 to 50 mg./kg. Arant (1952) reported the results of acute toxicity tests by oral ingestion to chickens. The LD-50 was found to be between 10 and 15 mg./kg. of body weight.

Hayes *et al.* (1951) reported results of experiments with acute and chronic doses of dieldrin to rats. Twenty-five per cent wettable powder formulations were used. Eight of 10 rats receiving a single dose of 400 mg./kg. died in 4 to 11 days and lost an average of 20 per cent of their original body weights. Eleven of 15 rats receiving the powder at the rate of 20 mg./kg. daily, five days per week, died after receiving an average of eight doses each, and lost 30 per cent of the original body weight. Hayes *et al.* (1951) applied dieldrin in xylene solutions to the skin of rabbits. The LD-50 was 184 mg. per kg. of body weight, with confidence limits of 139 and 243 mg./kg. at the 5 per cent level of probability. Eden (1951) reported the results of experiments on the acute toxicity of dieldrin by oral ingestion to 3- and 6-week old chickens. The LD-50 for both age groups was between 20 and 30 mg./kg. of body weight.

The toxicity of toxaphene to warm-blooded animals has been reported by several investigators. Batte & Turk (1948) in studies on the toxicity of toxaphene by acute oral doses to dogs stated that 20 mg./kg. did not produce death but did cause convulsions. Parker & Beacher (1947) found by patch test studies on 200 unselected human subjects that toxaphene was neither a skin irritant nor a skin sensitizer. However, Harfield (1949) stated that it was moderately irritating to the skin, was absorbed through the skin, and that over 2.4 grams daily on the skin was dangerous. He estimated the fatal oral dose to man was 2 to 6 gm./kg. of body weight.

PROCEDURE.—Test animals were 2- to 3-pound rabbits purchased from a commercial source. The rabbits were weighed and dipped in varying concentrations of wettable powder suspensions in water of aldrin, dieldrin, and toxaphene. The dipping procedure consisted of immersing a rabbit up to the neck in a specific volume of a known concentration of insecticide. The operation was done by two persons, one holding the rabbit in the formulation while the other kept the suspension agitated and rubbed into the hair of the animal. The rabbit was kept in the formulation for 2 minutes. When the rabbit was removed from the dip, the remaining volume was measured. The loss of volume of the insecticidal formulation provided the means of calculating the amount of insecticide deposited on the animal. After they were dipped, the rabbits were held in stocks for 2 hours to dry and to prevent licking. After the animals were dry, they were covered up to the necks in cloth bags which allowed ample room for moving about in the cages, eating, drinking, and elimination. Covering the animals in this manner prevented them from licking their bodies and ingesting the insecticides.

Treated animals were placed in individual cages and observed for 3 days for symptoms of toxicity. Post mortem examinations of several rabbits in each treatment were made to determine the damage to internal organs.

RESULTS.—Symptoms of poisoning were the same for all three insecticides. They were loss of appetite, extreme nervousness, and convulsions. Typically, a convulsion followed a gradual build-up in nervousness. The poisoned animal would run wildly about the cage, grit its teeth, fling itself against the cage, and finally fall on its side. While on its side, the animal would kick vigorously and stretch the head backwards over the back. The muscular spasms lasted 3 to 10 minutes, followed by a half hour of relaxation and hard breathing before recovery.

Results of the tests with aldrin are presented in table 1. There were no deaths at dosages up to 15.10 mg./kg. All rabbits receiving doses higher than 21.58 mg./kg. died. It was concluded that the LD-50 was between 15 and 25 mg./kg. of body weight. Autopsies revealed no noticeable abnormalities of the liver, lungs, and kidneys. There was slight hemorrhage in the subcutaneous tissue of the back and slight dilation of the veins in the intestines. Bloody froth was evident around the mouth and nose.

Results of the tests with dieldrin are presented in table 1. These data plotted in a dosage-mortality curve showed that the LD-50 was between 400 and 450 mg./kg. Autopsies revealed that the liver, lungs, heart, and kidneys were normal. There were slight hemorrhages in the subcutaneous tissues of the back and some dilation of the veins in the intestines. A bloody froth was evident around the nose and mouth.

The results of the studies on toxaphene are shown in table 1. These data plotted in a dosage-mortality curve place the LD-50 between 1025 and 1075 mg./kg. Autopsies revealed dilation of the veins and hemorrhages in the intestines. The liver was pale and mottled but the kidneys appeared normal.

SUMMARY.—The toxicity of aldrin, dieldrin, and toxaphene to rabbits by skin absorption was determined by immersing rabbits in water suspensions of wettable powders. The LD-50 of aldrin was 15 to 25 mg./kg.; of dieldrin, 400 to 450 mg./kg.; and of toxaphene, 1025 to 1075 mg./kg. Symptoms

Table 1.—Acute toxicity of aldrin, dieldrin and toxaphene wettable powder formulations in water to rabbits by skin absorption.

DOSAGE OF ALDRIN MG./KG.	NUMBER OF RABBITS		PER CENT MORTALITY
	Dipped	Killed	
10.52	1	0	0
12.20	1	0	0
15.09	1	0	0
15.10	1	0	0
21.58	1	1	100
21.60	1	1	100
24.61	1	1	100
25.91	1	1	100
32.40	1	1	100
MEAN DOSAGE OF DIELDRIN MG./KG.			
190.53	4	0	0
300.20	4	1	25
470.49	5	3	60
673.00	5	4	80
780.10	4	4	100
MEAN DOSAGE OF TOXAPHENE MG./KG.			
372.33	5	0	0
773.83	5	1	20
1074.30	5	4	80
1098.94	5	4	80

of poisoning for all three insecticides were loss of appetite, extreme nervousness, convulsions, and muscular spasms.

LITERATURE CITED

Arant, F. S. 1952. Toxicity of aldrin to chickens. JOUR. ECON. ENT. **45**(1): 121.

Batte, E. G. and R. D. Turk. 1948. Toxicity of some synthetic insecticides to dogs. JOUR. ECON. ENT. **41**(1): 102–3.

Eden, W. G. 1951. Toxicity of dieldrin to chickens. JOUR. ECON. ENT. **44**(6): 1013.

Harfield, Ira. 1949. Fly control chemicals and toxicities. Pests. **17**(6): 9–14.

Hayes, W. J., G. S. Bachelor, J. S. Cass, W. F. Durham, F. F. Ferguson and T. B. Gaines. 1951. Acute and chronic toxicity of water-wettable dieldrin to rats. U. S. Public Health Service. Summary of Activities No. 25.

Hayes, W. J., G. S. Bachelor, W. F. Durham, T. B. Gaines, E. Huey, J. A. Jensen, J. M. Johnston and W. T. Sumerford. 1951. LD-50 for dermally applied dieldrin to rabbits. U. S. Public Health Service. Summary of Activities No. 27.

Kitselman, C. H., A. R. Borgman and P. A. Dahm. 1949. Toxicological studies of Compound 118 (Octalene) on large and small animals. Abstract published in the program of 61st Annual Meet. A.A.E.E.

Lehman, A. J. 1949. Pharmacological considerations of insecticides. Assn. of Food and Drug Off. of U.S. **13**(2): 65–70.

Parker, W. L. and J. H. Beacher. 1947. Toxaphene, a chlorinated hydrocarbon with insecticidal properties. Dela. Agr. Expt. Sta. Bul. **264.**

Swaine Jack-Pine Sawfly in Wisconsin

DANIEL M. BENJAMIN[1] and NORBERT B. UNDERWOOD[2]

Cocoons of an unknown sawfly were collected beneath defoliated jack pine in the Sauk County Forest near Lone Rock, Wisconsin, on March 29, 1952.[3] Adult specimens reared from these cocoons were identified as *Neodiprion swainei* Midd. by the senior author. This collection record is of especial interest, as it represents the first report of this species in Wisconsin and an extension of its range to the south. Previous reports near Wisconsin have been from southeastern Manitoba and Saulte St. Marie, Ontario, Canada.[4]

Adult sawflies were observed ovipositing at the base of half-grown needles of jack pine early in June. First- and second-instar larvae were feeding gregariously on the old-growth needles early in July; fourth- and fifth-instar larvae were present during late July.

Reconnaissance surveys indicated that the infestation was confined to approximately 400 acres of planted jack pine. The red-headed pine sawfly, *Neodiprion lecontei* (Fitch), also was present on jack pine and red pine within the infestation area.

Control operations were conducted on July 15, 1952, when the majority of the larvae were in the second instar. A Stearman airplane was used to apply oil sprays containing 1 pound of technical-grade DDT per gallon of solution at the rate of 1 gallon per acre. This project, financed jointly by the Wisconsin Conservation Department and Sauk County, cost an average of $2.75 per acre sprayed. Forty-eight hours after spraying the reduction in larval population averaged 96 per cent.

[1] U.S.D.A., Agr. Res. Admin., Bureau of Entomology and Plant Quarantine.

[2] Forest entomologist, Cooperative Forestry Division, Wisconsin Conservation Department.

[3] Collection by C. B. Eaton, A. T. Drooz, and the senior author.

[4] Atwood, C. E., and O. Peck. 1943. Some native sawflies of the genus *Neodiprion* attacking pines in eastern Canada. Canad. Jour. Res., Sect. D, Zool. Sci., **21**: 109–144.

Peach Tree Borer Control[1]

DIAL F. MARTIN, *Texas Agricultural Experiment Station*

Paradichlorobenzene crystals (PBD) and ethylene dichloride emulsions are generally used for the control of the peach tree borer, *Sanninoidea exitiosa* (Say), in Texas. Effective control may be obtained with these fumigants but safer materials and less expensive methods of applications are needed. Interest in tree-trunk spraying for the control of the peach tree borer resulted following reports by Driggers & Smith (1944) of reduction in peach borer population in experiments using DDT for Japanese beetle and oriental fruit moth control. LaPlante & Wheeler (1948) showed that DDT applied to trunks, crotches and limb bases at 3-week intervals, beginning with the first hatch, was effective in controlling the peach tree borer and that one application of benzene hexachloride containing 4 ounces of gamma isomer in 100 gallons of water was almost as effective as two sprays of DDT. Bobb (1949), using 4 pounds of actual DDT in 100 gallons of water, obtained effective control with two applications, the first in early July and the second in mid-August. His results also indicated that parathion used at the rate of 1 pound of 25 per cent material in 100 gallons of water gave excellent control in an orchard with a light infestation and good control in a heavily infested orchard.

Snapp (1950) reported ineffective control with DDT and benzene hexachloride applied as dusts to the trunk and lower part of large limbs. Benzene hexachloride dust applied in a continuous band around the base of the tree and covered with soil was also unsatisfactory. Single applications of a number of chlorinated hydrocarbons and 2 phosphorous compounds sprayed on the trunks and lower limbs, were not effective. Three applications of 8 pounds of 6 per cent gamma isomer of benzene hexacloride in 100 gallons of water were about as effective as the recommended fumigant-type treatments.

METHODS AND MATERIALS.—Tests were started in 1951 near Jacksonville, Texas, on 6-year-old peach trees to determine the effectiveness of tree-trunk applications of DDT, chlordane, EPN, dieldrin, and lindane. Two soil fumigants, PDB and ethylene dichloride emulsion, were included in these tests. The dosages used are shown in table 1. The spray applications were made at monthly intervals beginning July 17, utilizing a conventional orchard sprayer operating at 400 pounds of pressure. A single-nozzle spray gun was used to direct the spray against all sides of the tree trunk from the crotch to the ground level. Two to 3 quarts of spray were required to cover each tree trunk.

Plots, each consisting of three trees, were selected at random to receive applications of each of the seven insecticides tested. The trees within each plot were randomized and each tree was treated with one of the following schedules using each insecticide: (1) one application, July 17, (2) two applications, July 17 and August 21, and (3) three applications, July 17, August 21 and September 22. All treatments were replicated 6 times. An untreated check plot was included in each replicate. Ethylene dichloride emulsion and PDB treatments were applied November 17, 1951.

[1] Technical Contribution No. 1728, Texas Agricultural Experiment Station.

Table 1.—Results of insecticidal tests for the control of the peach tree borer, Jacksonville, Texas, 1951–52.

Materials per 100 Gal. of Water	Number		Average Borers per Tree	Per Cent Reduction
	Applications	Trees		
Sprays				
DDT, 8 pounds, 50% WP[1]	1	6	3.7	78.8
	2	6	1.2	93.2
	3	6	0.8	95.2
Chlordane 2.5 pounds of 40% WP	1	6	5.8	66.3
	2	6	2.2	87.4
	3	6	2.2	87.4
EPN, 1 pound 25% WP	1	6	8.8	48.9
	2	6	7.0	59.5
	3	6	2.7	84.5
Dieldrin, 2 pounds 25% WP	1	6	5.5	68.2
	2	6	4.8	72.0
	3	6	0.5	97.1
Lindane, 1 pound 25% WP	1	6	2.7	84.5
	2	6	1.3	93.3
	3	6	0.2	99.0
Fumigants				
PDB, 1 ounce per tree	1	18	0.8	95.5
Ethylene dichloride emul. 0.5 pint 25% emul. per tree	1	18	0.6	97.5
Untreated check		18	17.3	

[1] Wettable powder.

Counts of borers were made in June, 1952. All examinations consisted of removing the soil from the immediate vicinity of the tree trunk down to a depth of several inches. Cuts were made into the bark and cambium at all points below the ground level where indications of borer damage could be observed. The borers were removed from each tree, counted and preserved in 80 per cent alcohol. No attempt was made in this count to separate the species of peach tree borers.

RESULTS.—Results of these experiments are shown in table 1. A reduction of the borer population was noted on all trees receiving one or more applications of the insecticides. As the number of spray applications was increased, infestation of borers decreased.

SUMMARY.—The borer population was reduced 95 per cent or more in all trees receiving 3 applications of lindane, DDT and dieldrin. The borer reduction on trees receiving two applications of DDT and lindane showed 92 per cent or more reduction. Less than 90 per cent reduction in borer population was obtained with three applications of chlordane and EPN. Trees receiving one application of EPN had less than a 50 per cent reduction of the borer population. Paradichlorobenzene and ethylene dichloride emulsion gave 95.5 and 97.5 per cent borer reduction respectively.

LITERATURE CITED

Bobb, M. L. 1949. Sprays for control of the peach tree borer. JOUR. ECON. ENT. 42(2): 343–5.

Driggers, Byrley F. and Charles L. Smith. 1944. Field tests of DDT to control the peach tree borer. JOUR. ECON. ENT. 37(4): 537.

LaPlante, A. A., Jr. and E. H. Wheeler. 1948. DDT and benzene hexachloride in sprays to control peach tree borer. JOUR. ECON. ENT. 41(2): 240–4.

Snapp, Oliver I. 1950. DDT and some of the newer insecticides for control of peach tree borers. JOUR. ECON. ENT. **43**(3): 315–8.

An Ecological Study of Three Species of Mites on American Linden

WALTER C. ATCHESON *University of Maryland, College Park*

During July and August, 1952, the foliage of lindens on the campus of the University of Maryland turned brown or rusty prematurely. Examination disclosed three mites and one aphid numerous on the leaves. The aphid secreted honey dew upon which a sooty mold was growing. This aphid was *Therioaphis tilia* (L.).[1] The mites[2] were *Typhlodromus sp.*, a predator, *Czenspinskia lordi* Nesbitt, which fed on vegetable matter, particularly on the sooty mold, and *Tetranychus canadensis* (McGregor). Near the top of the trees there was a severe thinning out of the foliage due to the feeding of *T. canadensis*. Many of the leaves fell earlier than usual. The mites did not feed in large numbers on the lower foliage.

Typhlodromus sp. is visible to the unaided eye and is a light color or almost transparent. *Czenspinskia lordi* is yellowish in color, with two or three distinct spots on the dorsum caused by laterally placed "oil" or excretory glands. *T. canadensis*, in the overwintering stage, is a bright orange color. It is similar to *T. schoenei* McGregor. All of the mites were found on the underside of the leaves.

A sample of 50 leaves was taken from three trees on six different days to determine the population count. *Czenspinskia lordi* was found to be most numerous. There were from 25 to 200 of these mites on a leaf. *Typhlodromus sp.* was not as abundant. There were from none to 12 on the leaves. *T. canadensis* was found only occasionally.

Czenspinskia lordi was found in the pronymphal stage in September. The average length of a female was .25 mm. No males were found, and there were no eggs that produced *C. lordi*. Parthenogenesis was possible. *Typhlodromus sp.* was also found in different stages of its life cycle, although as in the case of *C. lordi* no eggs were found. Attempts to raise the mites in the laboratory met with failure due to the aging of the leaves. *C. lordi* was found in large numbers on the branches of the leaves during the middle of October and *Typhlodromus sp.* was found overwintering in the adult stage on the trunk of the trees.

During the latter part of October and November, *Czenspinskia lordi* was found overwintering under the bark on the limbs in round, almost flattened cases. These cases are light brown in color. There were several nymphs in one case. However, the mite was also found overwintering alone. Samples of the soil taken from around the base of the trees produced *T. canadensis* in the adult form. No eggs were found at this time.

The greatest damage by the mites was in the upper part of the trees where a severe thinning of the leaves occurred. The build-up of mites reached a peak by mid-July. *Therioaphis tilia* (L.), an aphid, was an important factor in sustaining *Czenspinskia lordi*. The aphids, feeding on the leaves, secreted honey dew that turned black on the leaves. The honey dew supported the growth of fungi. *C. lordi*, a vegetable feeder, thrived on this. The predator, *Typhlodromus sp.*, was thought to feed on the nymphs and adults of *C. lordi* and *T. canadensis*, although this was not observed. The mites were not controlled by this predator.

[1] Det. by Louise Russell, U.S.D.A., Bureau of Entomology and Plant Quarantine.

[2] Det. by E. W. Baker, U.S.D.A., Bureau of Entomology and Plant Quarantine.

LITERATURE CITED

Baker, E. W. and G. W. Wharton. 1952. An Introduction to Acarology. Vol. 1, pp. 344–5.

Comstock, J. H. 1948. An Introduction to Entomology. Pp. 215, 515.

Garman, P. 1948. Mite species from apple trees in Connecticut. Bul. 520: 5–27.

Nesbitt, H. H. J. 1946. Three new mites from Nova Scotia apple trees. The Canadian Entomologist, **78**: 15–22.

Pritchard, A. E. and E. W. Baker. 1952. A guide to the spider mites of deciduous fruit trees. Hilgardia **21** (9): 253–86.

Control of Green June Beetle Larvae in Alfalfa Fields with Parathion

C. B. DOMINICK, *Field Station, Va. Agr. Expt. Sta., Chatham*

During recent years larvae of the green June beetle, *Cotinis nitida* (L.), have become an important pest in alfalfa fields in Southside, Virginia. Alfalfa grown on light sandy soil types relatively high in organic matter are more susceptible to infestation by the insect than where the crop is grown on stiff heavy soils. The larvae feed largely on organic matter on, or near the soil surface and heavy infestations pulverize the soil. Characteristic surface activity is most noticeable during the spring and early fall when the grubs are in the third instar and feeding is rather extensive. It is the practice of many growers to top-dress alfalfa with barnyard manure during the winter months, thus providing favorable oviposition conditions for the green June beetle. In established stands of alfalfa the extent of the damage, other than the depletion of the soil of organic matter and probably providing conditions more favorable for greater water losses, has not been determined. A new stand of alfalfa on heavily infested soil is often greatly reduced or completely destroyed during the spring and fall, particularly during dry periods when the seedlings are small and making little growth.

During mid-October 1952, an experiment was conducted near Chatham, Virginia, in a relatively heavily infested established stand of alfalfa which had recently been clipped. The green June beetle larval population as indicated by surface activity was relatively uniform.

MATERIAL AND METHODS.—Parathion was used in two formulations: a 0.75 per cent parathion dust and a 0.75 per cent parathion on granular tobacco. To provide for better distribution and to prevent drifting, the required amount of parathion dust for each plot was mixed with an equal weight of moist sand. The materials were applied broadcast by hand on October 16 following a light rain.

The plots were 18 feet square, and were replicated

four times in a randomized-block design. A buffer zone 4 feet wide separated plots on all sides. The results were determined by collecting the dead and morbid grubs from a 1 square yard area located in the center of each plot. A 2-inch barrier was placed around the areas selected for sampling to discourage migration. Larvae were collected and counted daily for the first 3 days and at intervals of 2 days for the following 4 days. The final counts were made by the use of a parathion drench, 8 ounces of 15 per cent wettable powder in 25 gallons of water, applied at the rate of 1 gallon per square yard. Although it is highly probable that not all larvae come to the surface, it is believed that such a method gives a fairly accurate picture of the infestation and the degree of control obtained.

DISCUSSION AND RESULTS.—The results are presented in table 1. Under the conditions of the experiment, parathion gave effective control although the treatments were applied rather late in the season. The data indicate that the parathion dust-sand mixture and parathion on granular tobacco gave a similar reduction in green June beetle larvae after 7 days. Both formulations were more effective at 0.75 pound per acre than at one-half this dosage. The largest number of larvae were found on the soil surface the first day following the 0.75 pound treatment, while this was true on the second day for the 0.375 pound dosage. A high percentage of the larvae were collected on the soil surface the first 3 days following treatment.

Table 1.—Comparative tests with parathion for the control of third instar green June beetle larvae in alfalfa fields.

		Average Number of Larvae Recovered		
Treatment[1]	Formulation	Soil Surface	After Applying Parathion Drench	Per Cent Reduction 7 Days
Parathion				
0.75	Granular	27.4	1.0	96.5
0.75	Dust-sand	20.4	1.0	95.3
0.375	Granular	18.4	2.5	88.0
0.375	Dust-sand	23.7	3.3	87.8
Check		0.0	22.5	—

[1] Actual parathion.

It appears from the data that parathion at the rate of 0.375 pound per acre, if applied sufficiently early and under favorable conditions will give adequate control. As many growers seed or re-seed alfalfa on infested soil without being aware of the presence of large populations of green June beetle larvae, the parathion treatment offers a rapid, effective control of the insect under such conditions.

Maggot Therapy of Actinomycosis[1]

ROBERT J. DICKE, *Department of Entomology, University of Wisconsin*[2]

In the early stages of actinomycosis or lumpy jaw appreciable success in arresting the development of the disease may be obtained with chemotherapeutic agents or X-ray. When the disease reaches an advanced stage and involvement of the mandible occurs, treatments are seldom, if ever, successful even in arresting its progress. Such animals are usually sent to slaughter. However, with animals valuable as breeding stock, any treatment which will arrest the disease and prolong the productive life of the animal is of considerable economic importance to the breeder. The results of maggot therapy in a valuable herd sire which had failed to respond to other treatments are reported in this paper. This procedure was suggested by the work of Baer in the treatment of human osteomyelitis.[3]

DESCRIPTION OF INFECTION.—The animal involved was a Guernsey bull six years of age and weighing approximately 1300 pounds. An actinomycotic lesion had involved the mandible for at least two years prior to this study. The disease was clinically diagnosed as actinomycosis, and the etiological agent, *Actinomyces bovis*, was demonstrated.[4] A large bony mass about 6 inches in depth and 10 inches in length protruded from the mandible and involved the entire right side of the head. The lesion was a tough spongy tumor-like structure which had broken through the jaw bone and skin. Deep sinuses perforating the osseous structure were plugged with excrement. Upon uncovering these, a thick yellow pus with an extremely foul odor was discharged. Large areas of skin at the margins of the mass were denuded, swollen and inflamed. The eye was closed due to the distention of associated tissues. Several suppurating lesions occurred in the parotid region. Intense irritation was apparent since the animal constantly rubbed or bumped the actinomycotic growth against hard surfaces. The bull was emaciated, in very weak condition, respired with difficulty and could rise to a standing position only with extreme effort. Although the tongue, mouth or throat apparently were not involved, the animal was unable to masticate and swallow food. Involvement of the lungs was not determined.

PROCEDURE.—A breeding culture of the blow fly, *Phaenicia sericata* (Meigen), was maintained on medium consisting of equal parts of ground raw liver and beef. One half pound of medium was required for a culture of approximately 100 larvae. The medium was contained in a pint sized, waxed paper carton commonly used for packaging dairy products. This carton was enclosed within a 1 gallon sized carton, the bottom of which was covered with a layer of sand for pupation. Upon completion of larval development, mature maggots crawled from the medium carton to drop into the layer of sand for pupation. Mature flies were fed on fresh liver and a dilute mixture of honey, water and yeast. Flies oviposited readily on strips of liver placed on moist filter paper contained in a Petri dish. First instar maggots (approximately 24 hours after eclosion) developed on the liver strips were used to inoculate the diseased tissue of the animal. A sterile rearing technique, essential for human therapy, was not employed.

Maggots, in lots of several thousand, were applied to the diseased area with a spatula. The maggots immediately burrowed into and became established within the deep sinuses of the granulomatous mass. Upon completion of their development, mature maggots dropped from the lesions to the ground for pupation. During the months of October through May,

[1] Approved for publication by the Director of the Wisco sin Agricultural Experiment Station.

[2] The cooperation of Mr. Edwin A. Gallun, owner of the Anchor Point Farms, Nashotah, Wisconsin, is acknowledged for permission to conduct this experiment on their herd sire, Argilla Moderator.

[3] W. S. Baer *The Treatment of chronic osteomyelitis with the maggot (larva of the blow fly)*. Jour. Bone and Joint Surg. 13 (3): 438–75. 1931.

[4] Diagnosis by Dr. G. A. Dick, Professor of Veterinary Surgery and Obstetrics of the University of Pennsylvania, where the animal had been treated by X-ray therapy two years previously.

applications of maggots were made at two week intervals. Spontaneous infestation by maggots occurred during the summer months which then included *Phormia regina* (Meigen) as well as *Phaenicia sericata.*

RESULTS.—On the day following the initial application of maggots, a copious, purulent discharge occurred from the sinuses of the principal lesion. Several days later the peripheral swelling and inflammation subsided, and the animal was able to masticate and swallow food. Within a period of three months, the animal's physical condition and vigor had gradually improved until feeding and respiration were normal, and breeding activity was normal and active. The parotid lesions had healed, and the peripheral tissues including the eye were no longer involved. The intense irritation so evident before treatment apparently was reduced to such a degree that the animal no longer rubbed the infected area. After a period of 6 months, the bull was reasonably normal in vigor and general condition, and was again utilized as the principal herd sire. Moderate suppuration continued from the principal lesion. All peripheral inflammation had disappeared, and formerly denuded areas of skin were again covered with normal hair. After a year of service (18 months after initial treatment), the bull's semen became markedly reduced in viability, and the animal was slaughtered. The animal, however, was still vigorous, although breathing had become more difficult, along with a general emaciation. This terminal condition may have been due to an actinomycotic involvement of the lungs.

CONCLUSIONS.—Maggot therapy, utilizing septic larvae of a blow fly, *Phaenicia sericata,* was successful in arresting an advanced mandibular infection of actinomycosis. Results of this treatment were remarkable in effecting a rapid initial recovery from a moribund condition and extending the animal's life to a year's normal service as a herd sire.

Effect on the Oriental Fruit Moth of Materials Used for Plum Curculio Control

OLIVER I. SNAPP, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Some of the materials included in field-plot experiments for control of the plum curculio, *Conotrachelus nenuphar* (Hbst.), on peaches in recent years at Fort Valley, Georgia, have value against other injurious species, including the oriental fruit moth, *Grapholitha molesta* (Busck). It has been the practice, therefore, to examine harvested peaches from such plots for oriental fruit moth as well as for curculio injury. A general summary of the results obtained in 1951 and 1952 is given below.

MATERIAL	POUNDS PER 100 GALLONS	NUMBER OF APPLICATIONS	PER CENT OF PEACHES INFESTED
Tests in 1951			
Parathion, 15% WP	3	4	1.5
EPN, 25% WP	2	4	1.5
Methoxychlor, 50% WP	2	4	8.7
Lead arsenate	2	3	6.8
Aldrin, 25% WP	2	4	15.0
Dieldrin, 25% WP	2	4	17.1
Tests in 1952			
Parathion, 15% WP	2	5	4.1
EPN, 25% WP	1.5	5	5.4
Lead arsenate	2	4	11.7
Dieldrin, 25% WP	2	4	18.8

It is seen that parathion and EPN were the most effective materials in preventing oriental fruit moth injury. Parathion also ranked first in 1949 and 1950.

Differential Tolerance to Parathion of Two *Typhlodromus* Predatory on Cyclamen Mite

C. B. HUFFAKER and C. E. KENNETT, *Department of Biological Control, University of California, Albany*

Field population studies on natural control of cyclamen mite on strawberries by Huffaker & Kennett (1953) revealed the existence of two or more predatory mites of the genus *Typhlodromus* with marked differences in tolerance to dust treatments with parathion. General tests on this difference were made in the laboratory. The results are important in the clarification of the cyclamen mite and its predator populations recorded by those authors.

Typhlodromus occidentalis Nes.[1] persists after repeated direct and very heavy treatments with parathion, whereas *T. reticulatus* Oud.[1,2] is consistently destroyed by parathion treatments, and is unable to survive on such plants after periods of two or even three months subsequent to treatment. Also, the slightest drift of parathion from adjacent rows or crops has been very detrimental to this species.

Table 1.—Laboratory tests on effect of parathion on two *Typhlodromus*.

PREDATOR	NUMBER OF INDIVIDUALS	TREATMENT	PER CENT DEAD IN 24 HRS.
Typhlodromus reticulatus[1]	30	Parathion 2%	100
T. occidentalis	30	Parathion 2%	37

[1] And/or *T. cucumeris.*

After some effort it became possible to separate live adults of these two forms. A camel's hair brush was used in making the transfers. Field populations were thus separated and tests conducted on the immediate effects of parathion. Strawberry leaflets were pinned to a cardboard sheet and dusted with 2 per cent parathion. In 10 to 15 minutes the leaflets were placed in small vials with the predators; that time being required to complete the procedure. Table 1 shows the results of these tests.

It is obvious that though *Typhlodromus reticulatus* is very susceptible to this acaricide, *T. occidentalis* has a high degree of tolerance to it. By considering also the inaccessibility to dusts of many micro-habitats and the less active behavior of this species in field strawberries, compared to *T. reticulatus,* together with the repeated experience of its persistence

[1] Examples kindly determined by Dr. H. H. J. Nesbitt.
[2] And/or *T. cucumeris* Oud.

and the relatively complete destruction of *T. reticulatus* following field treatments with parathion, there remains no doubt that this species is far more tolerant to field applications of parathion than is *T. reticulatus*.

LITERATURE CITED

Huffaker, C. B. and C. E. Kennett. 1953. Developments toward biological control of cyclamen mite on strawberries in California. JOUR. ECON. ENT. **46:** (In press.)

Insect Vectors of Oak Wilt Fungus

C. L. GRISWOLD and R. B. NEISWANDER,
Ohio Agricultural Experiment Station, Wooster

In an attempt to determine the vector of the oak wilt fungus, *Chalara quercina*[1] Henry, investigations of the insects that occur on both diseased and healthy oaks were begun at Wooster in October 1951. Inasmuch as the Dutch elm disease fungus, which is transmitted by bark beetles, is related to the oak wilt fungus, a search was made immediately for bark beetles that might be associated with oak wilt. Three minute species, all belonging to the genus *Pseudopityophthorus*, were found breeding commonly on oak trees that had been killed by the oak wilt disease. These were collected in considerable numbers and carried to the laboratory at Wooster where they were reared in cages.

It was learned that the insects breed in recently cut or dying stems or branches varying from 0.5 to 5 inches in diameter. The adults of two species, *Pseudopityophthorus minutissimus* (Zimm.) and *P. pruinosus* (Eichh.), were found to leave such areas occasionally to feed in the small twigs of healthy trees. Consequently it seemed possible that they might be responsible for transmitting the fungus.

A number of cages were constructed each of which contained a small oak tree growing in an 8-inch pot and a section of diseased wood containing many bark beetles. In nearly every case bark beetles soon left the diseased wood to feed on the small twigs of the healthy tree. Several such trees developed symptoms similar to those caused by oak wilt, but plant pathologists were not able to isolate *Chalara quercina* from those cultured. It is probable the mechanical injury caused by the feeding of the beetles was sufficiently severe to cause discoloration and wilting of the foliage. However, it is known that the disease organism dies rather quickly after infected wood becomes dry and it is possible that the plants were not cultured at the proper time to isolate the organism. Many of the trees treated in the manner described above are now dormant and will be observed closely for symptoms of oak wilt when growth starts in the spring.

In an article by T. L. Guyton in the *Plant Disease Reporter*, Vol. 36, No. 10, it was stated that a row of red oak trees approximately a half mile long in Bedford County, Pennsylvania had been blazed late in April, 1952, to mark a woodland trail. By September 17 three-fourths of the blazed trees were dead as a result of oak wilt infection. The nearest oaks believed to have died from oak wilt were located approximately one-fourth mile from the blazed trees.

Consideration of this report led to the suspicion that bleeding wounds in healthy oaks might serve as points of ingress for the oak wilt fungus. It was recalled that one or more unidentified species of *Drosophila* were abundant in a woods in central Ohio where many trees died from oak wilt. Furthermore, difficulty had been experienced in preventing adults of the pomace fly, *Drosophila melanogaster* Meig., from entering culture dishes containing sporulating mats of *Chalara* in the laboratory at the Ohio Agricultural Experiment Station. Consequently, investigation of *D. melanogaster* Meig. as a possible oak wilt vector was begun late in October 1952.

It was learned that the *Drosophila* adults were strongly attracted to sporulating *Chalara* mats. Both sexes fed on the very small droplets of moisture present at the tips of the hyphae where the fungus endospores are normally formed. It was noted also that the females laid eggs readily in the mats and that adult progeny subsequently developed.

The pomace flies were also found to be strongly attracted to the bleeding wounds on the twigs of healthy oaks caused by the two species of bark beetles mentioned. Many of the flies were found clustered on such wounds feeding on the sap.

A microscopic examination of several *Drosophila* adults that had fed upon and deposited eggs in sporulating *Chalara* mats revealed that endospores of the fungus were present externally on the legs and internally throughout the intestinal tract. A similar examination of regurgitation droplets and excrement from such adults revealed large numbers of *Chalara* endospores.

Six *Drosophila* adults which had been confined in culture dishes containing sporulating *Chalara* mats were transferred to sterile agar and permitted to walk over it for a period of from 1 to 2 minutes. Subsequently 16 colonies of *Chalara* developed on this agar.

It is evident, therefore, that the pomace flies are attracted to both *Chalara quercina* mats and to bleeding wounds in healthy oaks, and that the adult flies may carry viable endospores of the fungus. It remains to be demonstrated that the fungus will grow in the bleeding wounds and penetrate the sapwood of such trees.

By the time this stage of the investigation was reached all but three of the oak seedlings available for disease transmission experiments had already entered dormancy. Bleeding wounds were produced on the twigs of these three seedlings by subjecting them to feeding attacks by bark beetles. The plants were then placed in screen cages containing many pomace flies. Culture dishes containing sporulating *Chalara* mats were also introduced from time to time. The seedlings were permitted to remain in the cages until the wounds became dry, and were then taken out-of-doors for the winter.

In view of the tremendous interest that has developed in the oak wilt disease and its method of dissemination it is felt that the information contained in this note should be of interest to other investigators. Certainly the points already demonstrated warrant the undertaking of intensive investigations on both *Drosophila* and *Pseudopityophthorus*.

[1] This paper was in type before the name of the oak wilt fungus was changed to *Endoconidiophora fagacearum* Bretz.

Pea Aphid Injury in Alfalfa Seed Fields

HERMAN F. MENKE, *Entomologist, Andrews Seed Company, Harrah, Washington*

The pea aphid, *Macrosiphum pisi* (Kltb.), has been but a minor pest in Washington alfalfa seed fields until the summer of 1952. Usually they are numerous on first crop and sometimes on second cutting (seed crop) until mid-July, by which time most of them have migrated. During the 1952 season there were numerous cases where infestations on alfalfa lasted until mid-August.

Since this pest has not maintained damaging populations during past years, field men and State College research entomologists were reluctant to recommend controls. In 1952, aphids were found in such numbers that enough could be collected in 40 sweeps of a standard 15 inch net to fill a coffee cup. Ten per cent DDT dust with 1 per cent parathion at 25 pounds per acre was used in many cases for prebloom lygus and aphis control. Within 3 to 4 weeks following such control, aphids had often built back to considerable numbers. This was apparently due to the general severe infestation in all of the central Washington seed areas and great numbers of winged forms moving into fields soon after first controls were applied.

Usually alfalfa was in full bloom when the reinfestations occurred so parathion used to control these aphids caused severe poisoning of both honey bees and alkali bees, *Nomia melanderi Ckll.* One per cent TEPP dust applied at the rate of 30 pounds per acre gave very poor control, but one quart of 40 per cent miscible TEPP with 5 gallons of water gave excellent control when applied at 6 P.M. One pint of this material did not give adequate control. The day had to be hot and quiet when the TEPP was used. Some foliage injury was observed with the treatment which was very similar to that reported on alfalfa in California by Smith & Allen (1948), with one quart of 50 per cent HETP per acre in a No. 1 base oil, at approximately 5 gallons of oil per acre. They found foliage injury only in HETP plots and not in any others where oil was also used so the injury must have been caused by the HETP. Their report stated, "Although very evident, the injury was at no time serious. The injury usually consisted of a variable amount of general chlorosis and small light necrotic areas surrounded by darker rings. Sometimes much of the peripheral area of the leaf was necrotic."

Principal damage by aphids appears to be severe stripping (fall) of alfalfa florets. The flower fall is probably the result of physiological damage to the plant. Sometimes four to ten aphids could be found on one raceme. An example of the loss caused by a severe aphis infestation is available. A 75-acre certified Ranger seed field had the following crop history. One half of this sprinkler irrigated field was cut for hay 7 days before the other half. When the early portion was in the bud stage, a field check indicated only lygus present so 10 per cent DDT dust at 25 pounds per acre was used; 10 days later the remaining portion had lygus and quite a few aphis; for this, DDT dust was used with one per cent parathion. Thirty days later, about July 30, the grower decided to control a severe aphis infestation in the early treated portion of the field. He used 10 per cent DDT dust with 1 per cent parathion at 25 pounds per acre and obtained excellent control. No subsequent control was necessary on the part treated with DDT-parathion. Irrigation and harvesting was the same on both areas of this field. The aphis infested area produced 358 pounds of clean seed per acre, and the controlled portion yielded 764 pounds per acre.

Aphis have been underestimated as a pest on alfalfa seed. Principal injury appears to be severe stripping when infestations occur during the seed setting season, and gumming of plants due to honeydew secretion if late infestations occur. Control measures should be taken when one-quarter a coffee cup can be filled with the aphis collected in 40 sweeps of a standard 15 inch net.

A good general practice seems to be the use of one per cent parathion dust with the first DDT application for lygus control if there are any aphids in the field. For later control of aphids, when the alfalfa is in bloom, one quart of 40 per cent miscible TEPP with five to eight gallons of water per acre, applied after 6 P.M. appears to be best because of bee poisoning hazards.

LITERATURE CITED

Smith, Ray F. and W. W. Allen. 1948. Alfalfa butterfly tests. California Agriculture, 2(4): 19–20.

The Effect of Cellulose Acetate Sheets on *Lasioderma serricorne*[1]

J. B. SIMEONE, *State University of New York, College of Forestry, Syracuse, New York*

Cellulose acetate sheets, due to the ease with which they can be fashioned into containers of various sizes and shapes, are often used in the construction of cages for rearing insects. The toxicity of these plastic sheets to plants and fish, when the plasticizer is diethyl phthalate, has been established by Maramorosch (1952). Since the same kind of material is being used by the author to rear beetles causing the deterioration of wood, this study was warranted to determine whether or not the plastic is also toxic to insects.

The cellulose acetate was purchased in January, 1950, 27 months prior to the initiation of these tests. The material is in sheets 20 inches wide, 50 inches long, and .03 inches thick. Confirmation that these sheets had been plasticized with diethyl phthalate was obtained from the manufacturer.

To test the effect of this material on insects, eggs of the cigarette beetle *Lasioderma serricorne* Fab. were used. These were laid in paprika within a period of 24 hours after introducing adults of both sexes. The eggs were then separated for two experiments, the first to determine the effect of the plastic in large cages similar to those already in use by the author, and the second to study the effect on insects when they are confined with the plastic in small containers.

EXPERIMENT 1.—A plastic sheet 18 by 39 inches was curved on its longer axis to form the top and two sides of a large cage in quonset hut fashion. Each end was held rigidly by 14-gauge aluminum strips and enclosed with 24-mesh copper screen sealed with paraffin. The volume of the enclosure is 3312 cubic inches. This provides a ratio of 1 square inch of plastic surface per 4.7 cubic inches of cage volume.

Eggs were placed in groups of five with 0.5 gram of

[1] For the identification of *L. planicollis*, *L. balteatus* and *Cryptophilus* sp. the author is indebted to Drs. R. H. Arnett and C. F. W. Muesebeck of the U.S.D.A., Bureau of Entomology and Plant Quarantine, Division of Insect Detection and Identification.

paprika in 1-dram homeopathic vials stoppered loosely with cotton. Twenty of these vials were placed in the large cage, the base of which was then sealed with paraffin to a sheet of glass. The remaining 20 vials were placed outside the cage as controls.

The results of this test, based on the number of adults reared from the eggs under each condition, are given in table 1. It is evident from these data, after applying the χ^2 test, that the difference between the number of beetles reared from eggs confined in the cage and those placed outside the cage is not significant.

Table 1.—Lasioderma serricorna Fab. Adults reared from eggs.

TREATMENT	NO. EGGS IN TEST	NO. REARED TO ADULT
Confined in cage	100	39
Not confined	100	37

EXPERIMENT 2.—In this second experiment, the eggs were separated in groups of 10 in miniature beakers 13 millimeters in diameter and 8 millimeters in depth. These were made by severing the lowermost part from 1-dram homeopathic vials. The bottom of each beaker was covered with small pieces of pad paper on which the eggs were placed, previous attempts to hatch these eggs without the paper having been unsuccessful. Enough paprika was added to each beaker to cover the eggs.

Twenty of the loaded beakers, containing a total of 200 eggs, were then placed in each of three 90 by 20 millimeter petri dishes. In the first dish the eggs were used as controls. In the second a cellulose acetate hood was made slightly smaller than the bottom dish, but of the same shape, and was used to cover the beakers before the petri dish cover was put in place. The hood weighed 11.16 grams and its surface area of 33.86 sq. in. provided a ratio of one sq. in. of plastic surface per 0.06 cu. in. of petri dish volume. In the third a 0.625 in. strip of plastic was used to line the inside vertical edge of the bottom dish. The strip weighed 5.43 grams, its surface area of 16.5 sq. in. providing a ratio of one sq. in. of plastic surface per 0.13 cu. in. of petri dish volume. Comparing these ratios with that of the large cage used in experiment 1, the hood and the strip provide, respectively, 78 times and 36 times the plastic surface per unit of volume.

The petri dishes were placed in separate desiccators at room temperature. Relative humidity was maintained at 73 per cent with a potassium hydroxide solution according to methods described by Buxton (1931).

Comparisons were made at two stages of insect development: one at the beginning of the first larval instar to determine egg survival and another at the beginning of the second larval instar. The results of these comparisons are given in table 2. All individuals that survived the beginning of the second instar completed their development to adults.

Table 2.—Lasioderma serricorne Fab. Survival of eggs and first instar larvae.

TREATMENT	EGGS USED	EGGS HATCHED	LARVAE COMPLETING FIRST INSTAR
Plastic hood	200	22	0
Plastic strip	200	69	12
Control	200	76	73

In table 2, the difference between egg survival under the plastic hood and the control is highly significant as determined by χ^2 test, but there is no significant difference between the plastic strip and the control. However, when the data are extended to the number of larvae surviving the first instar a highly significant difference is evident between the control and both the plastic hood and the plastic strip groups.

From the data it may be concluded that cellulose acetate plasticized with diethyl phthalate reduces the expected number of survivals in rearing *Lasioderma serricorne* Fab. when the ratio of plastic surface to cage volume is high. In large cages, when this ratio is low, the effect is negligible to non-existent. Insects other than *L. serricorne* Fab. reared in large cages similar to the cage described in experiment 1, include *Lyctus planicollis* Lec., *Ptilinus ruficornis* Say, *Hadrobregmus carinatus* Say, *Platybregmus canadensis* Fisher, *Coelostethus notatus* Say, *Litargus balteatus* Lec., and *Cryptophilus* sp.

LITERATURE CITED

Buxton, P. A. 1931. The measurement and control of atmospheric humidity in relation to entomological problems. Bull. Ent. Res. 22(III): 431–47.

Maramorosch, K. 1952. Toxicity of cellulose acetate sheets to plants and fish. Science 115(2983): 236.

Vitula edmandsii as a Pest of Honeybee Combs

V. G. MILUM, *Department of Entomology, University of Illinois*

Although *Vitula edmandsii* (Pack.) is listed as and is commonly found as a scavenger in the nests of bumblebees in Illinois, the writer has reared the adults from larvae found infesting combs of honeybees at Bingham, Nebraska, and Hull, Wyoming. The latter were submitted in March after a winter in which the outside temperature ranged well below 0° F., with the combs stored in an unheated room. It was reported that most of the larvae seem to be killed during cold weather, but the moths reappear the following fall and considerable damage results to combs containing pollen.

On April 14, recently hatched larvae were established on brood combs containing collected pollen, at 72° F. The pinkish larvae completed their growth (0.6 inch) in approximately 25 days from the hatching of the eggs. On attaining full growth, the larvae usually crawl from the feeding mass for pupation, but at first the majority spin only a flimsy cocoon. Of 135 crawling larvae isolated on May 17, only 3 adults had emerged by May 29, 12 days later, making a total larval and pupal period of 45 days, although some emerged as much as 2 weeks later.

The variable developmental period is due to the tendency of some of the larvae to require a longer diapause period after which a more definite cocoon is spun before actual pupation. Of 40 full grown lar-

vae placed outdoors on October 29 and brought in November 5, some had spun snug cocoons by November 12, but others remained in their original flimsy tunnels. These were again placed outside until January 17, after a morning temperature below 0° F. Of 10 larvae returned to 72° F., the first actual pupa was noted on January 26, and the first adult on February 7, indicating a possible pupal period after the diapause of at least 14 days.

From a culture established on February 29, using day old adults, and maintained at 72° F., the first three adults of the next generation emerged on May 6, giving a total period of 65 days from laying of eggs to adults. However, on May 28, after 87 days, there still remained many pupae and a few larvae of this generation. Of a larger number of larvae isolated as they were crawling from the feeding mass for pupation, the actual emergence of 123 individuals as adults varied from 13 to 37 days, with some not recorded requiring longer. This again indicates that the variable larval diapause period is responsible for the great variation in the life cycle. Likewise, it is apparent that the diapause phase is the one in which the larvae survive the winter under natural conditions.

It may be of interest to note that the male larvae of *Vitula edmandsii* may be distinguished from the larger female larvae by the presence of the male testes which are apparent beneath the skin on the dorsal surface of the fourth abdominal segment of the older larvae. A similar condition exists in other species, including the codling moth, the Indian meal moth and the Mediterranean flour moth.

Uropoda agitans, a Mite Pest in Commercial Fishworm Beds

PHILIP C. STONE and GILBERT D. OGLES,
Department of Entomology, University of Missouri

The so-called fishworm mite, *Uropoda agitans* Banks (Uropodidae), was brought to our attention for the first time and in enormous numbers during the summer of 1951 in commercial fishworm beds in Branson, Missouri. This mite may have been transported to all parts of the country through the sale of small cartons of fishworms.

This is the only mite in the family Uropodidae which has been found to be of economic importance. Although not a parasite on the fishworms, it builds up to such large numbers in earthworm beds that it is of great importance to commercial fishworm producers. It eats moist corn meal fed to fishworms but never attacks live worms unless they have been injured and their body fluids are exposed. It seems to be ideally suited to breed in commercial fishworm beds where there is an abundance of food and where it finds optimum moisture conditions. It is of importance for with a high reproductive potential and with a minimum of environmental resistance it soon builds up in the fishworm beds to such numbers as to devour more food than the fishworms and thus becomes an expensive boarder. One grower of fishworms in Branson, Missouri, had beds which were equivalent to an area 22 by 6 feet. He usually fed the worms every 2 weeks and in the course of a year they consumed approximately a ton of corn meal. After the mites became abundant in his beds he had to feed the worms every 2 or 3 days to keep them from starving. When these mites were driven to the top of the beds by an insecticide, they formed a solid mass of from 1 to 1.5 inches thick over the entire beds. This mite was found to be very resistant to many insecticides and acaricides. Parathion at the rate of 0.01 per cent was the only insecticide tested that was found to eradicate them from the beds without harming the fishworms. Higher concentrations of parathion killed fishworms. This insecticide was applied to the surface of the beds with a water sprinkling can. The mites immediately responded by coming to the surface and then later returning into the beds to die. All stages of the mite were killed by parathion.

An Aspirator Modified for Sampling Large Populations

S. S. RISTICH and DAN LOCKARD,
Ohio State University

Innumerable aspirators have been made or modified to fit many purposes. Most of these, although ingeniously made, were inefficient for sampling large insect populations, grain or other inert materials. The most serious drawback was the time lost removing the venturi or the pick-up tube.

Recently Chao (1952) modified a T type venturi aspirator which he used for selecting 300 to 400 samples of stored grain insects. While Chao did reduce the hours of work and the tedious routine with his T type venturi aspirator it still had two drawbacks, (1) The adapter must be changed for different size vials. (2) Much time is lost with a screw type vial which must be twisted in and out.

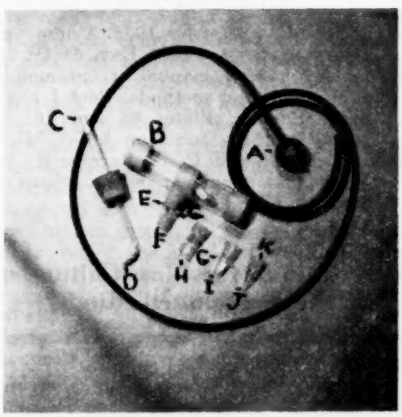


FIG. 1.—A. Barnhardt venturi. B. 1.625 inch tube. C. Pick-up tube. D. Bent end of pick-up. E. Stem of T-tube. F. Ground glass end. G. Horns. H, I, J. Adapters. K. Ground glass top of adapters. Note most ends wrapped with masking tape to prevent breakage.

The adapter on Chao's aspirator was modified to eliminate the time consuming steps. The stem of the T was ground to fit other ground glass adapters,[1] the ends of which were tapered to fit into any size vial or container. Both the ground glass stem and the

[1] Stock ground glass adapters can be purchased and affixed to each fixture with an oxygen-gas torch. In fact any person skilled in glass blowing could make this aspirator and the venturi, also.

adapters had two glass horns. A rubber band anchored over these glass projections kept the adapter secured to the ground glass stem.

These T type aspirators can be made in any size. The dimensions for this model are as follows: The barrel of the aspirator is made of 1.625 inch tubing 200 mm. long. The stem of the T (including the ground glass end) is 70 mm. in length. The end of the stem is ground to fit into the ground glass adapters which are 57 mm. long with a 21 mm. inside diameter. Each adapter has a tapered end of a different diameter to fit into any size vial or gas bottle. Horns on the adapters and the stem, are 7 mm. in length. Pick-up tubes are 7 and 10 mm. inside diameter and the bent end which projects into the throat of the stem is about 30 mm. long. The cork which holds the larger tube is bored off center so the bent end of the pick-up tube fits in the stem deeper. The venturi assembly is a brass Barnhardt type diagrammed in (Peterson).

Pick-up tubes with a larger diameter (10 mm. inside) than shown in the photograph can be made for larger insects, i.e., German roaches. This aspirator also has an inherent limitation. Insects or any inert object can not be collected directly into wire containers or jars that do not fit tightly around the ground glass adapters since the inrushing air through the openings (caused by a partial vacuum) forces the samples into the back of the tube. This fault, however, can be corrected if the screens are placed in vials and a heavy collar or the proper size cork is placed over the adapter to fit tightly on or in to the vial. Insects like Tribolium, however, can be collected into small vials and dumped into the wire containers more quickly.

LITERATURE CITED

Chao, Y. C. and A. Peterson. 1952. A new type of aspirator. JOUR. ECON. ENT. **45**(4): 751.

Peterson, A. 1949. A manual of entomological equipment and methods. Part I and II. Sixth Edition, Plates 68 and 160, Edwards Brothers, Inc. Ann Arbor, Mich.

Woodbury, E. N. and C. S. Barnhardt. 1939. Tests and crawling insects. Soap and Sanitary Chemicals. **15**: 95.

A Technique for Mass-Culture of the Six-Spotted Mite[1]

GLENN L. FINNEY, *Department of Biological Control, University of California, Albany*

In 1951, a small colony of *Stethorus vagans* Blackburn, a predatory beetle attacking the two-spotted mite, *Tetranychus bimaculatus* Harvey, was imported from Australia by the Department of Biological Control of the University of California at Albany for the purpose of establishing the species in California.

An insectary program was set up to culture these beetles in sufficient numbers to permit the release of sizeable colonies in the field during the brief period when conditions are optimum in areas representing the different ecological conditions where the two-spotted mite is a pest in California.

Attempts were made in the greenhouse to culture *Tetranychus bimaculatus* on various growing plants, including chard, sugar beets, horse peas, and celery. The celery plant, in exhibiting the greatest tolerance to heavy mite populations, was considered most satisfactory.

However, there were many factors involved that were incompatible with good insectary procedures. Greenhouse temperatures were difficult to control within the desired limits. Flats of plants were bulky, unwieldy units and required extensive greenhouse space for both the backlog of uninfested, growing units and the infested, working units. Other insects attacking the host plants, such as aphids, thrips, and whiteflies would build up in disturbing numbers. The most complicating factor was the appearance of a predatory mite of the genus *Typhlodromus* which built up swiftly under greenhouse conditions to a point where the host-mite infestation was virtually eradicated. This *Typhlodromus* was extremely resistant to TEPP which, because of its brief residual effect, was being used in the control of the greenhouse pests.

An insectary program under the best of conditions is beset with many potential hazards to success. These difficulties are increased many times when a culture of living host-plants is injected into the picture. Consequently, a vigorous search is generally made to find some other type of host material to be used as a substitute. To accomplish this another host insect sometimes must be utilized; even one that the parasite, or predator, does not ordinarily attack in nature.

In line with this principle, a colony of the six-spotted mite, *Tetranychus sexmaculatus* Riley was obtained. This mite can be cultured on ripe market oranges which are much more amenable to insectary manipulation since they can be handled in limited space in small, debris-free units under well controlled conditions. It became much easier to regulate host-predator relationships, since infested oranges could be added to units whenever necessary. The collection of beetle production was also greatly simplified.

However, using this procedure, it was found that a large area of the fruit surface was not utilized by the mites. The desired heavy population was limited to the vicinity of fruit-contact points. This restricted buildup was especially marked when very smooth-skinned oranges were employed. It was also observed that the mites congregated and fed around debris, such as strands of cotton or pieces of string laid across the fruit. This observation led to the idea of applying some short, fibrous, lint-like material to the surface of the orange.

The material first used was made from paper towels which were made into a compact roll about 1.5 inches in diameter and held tightly with rubber bands. The lint was formed by applying the end of this roll to the surface of a slow-turning sanding-disc using a coarse grade of sandpaper. This action reduced the paper to a fibrous lint rather than to an undesirable fine dust. The lint as it was formed was picked up by a tank-type vacuum cleaner.

Small oranges (288 pack) were used because the surface area per box was greater than in the larger sizes. Furthermore small oranges are usually priced much lower than the larger sizes.

The linting unit used in the program at Albany is rather small, accepting only four oranges at a time. The same principle could be applied to larger units with a consequent reduction in the number of operations if the size of the project would make it worth while. The unit consists of a glass jar 18 inches high and 9 inches in diameter. A circular platform made of hardware cloth, 0.5 inch mesh, is suspended about 6 inches from the top. A hole may

[1] Because only part of this note appeared (Vol. 46: 381) it is published in full here. Ed.

be cut or depression formed at each fruit position to prevent the oranges from rolling about. The top is made of cloth, either light muslin or organdy, stretched over a frame and laid over the jar.

Prior to use the oranges are held in a cold room or refrigerator. Just before they are to be linted they are removed and placed momentarily in a warm room. The slight condensation formed on the fruit is used to catch and hold the lint in place. The oranges are laid in position on their sides on the suspended platform so that there is space between each fruit. A pinch of lint is introduced into the jar and the top put in position. The air hose is placed in contact with the cloth top and a flow of air at a moderate pressure is directed downward through the cloth along the side of the jar so that the lint within is picked up and circulated upward around the oranges. This operation requires about four seconds and is repeated at about four points around the jar. If the lint has accumulated too heavily on the upper side of the oranges a parting shot of air will carry away the excess.

After this operation the oranges must be handled carefully so as not to disturb the lint. Each fruit should be picked up by grasping it between the thumb and finger at the button and blossom ends.

One difficulty with the use of paper lint was that the material tended to adhere closely to the damp fruit surface and therefore had to be applied very judiciously. If too much was used the purpose of the lint would be defeated by masking the feeding area from the mites. This difficulty was greatly alleviated by the development of lint from kapok fiber.[2] The long kapok fiber is reduced to short lengths by running it through an ordinary kitchen food grinder fitted with a fine-grind attachment. The lint is picked up with a vacuum cleaner. The shortest fibers are sifted out for use and the remainder re-run through the grinder.

The kapok fiber is very resilient, which property it retains when applied to the damp surface of the fruit. There is consequently more latitude in the application of kapok. Although the ideal coverage is one that is light and uniform, there is little harm done if the lint is put on heavier than necessary.

The mites are transferred to uninfested linted fruit by laying them on rows of infested fruit. The period of time these are left in contact depends on the kind of infestation desired. The rate of transfer depends upon the population pressure and the degree of exhaustion of the feeding area on the infested oranges.

The linting technique using kapok fiber promoted heavy, uniform populations of *Tetranychus sexmaculatus*, thus making oranges a very efficient host-supporting material which contributed in no small degree to the smooth operation and success of the program as a whole.

[2] This step was developed by Max Badgley of the Department of Biological Control of the University of California at Riverside.

Detached Leaf Culture in Mite Nutrition Studies[1]

J. G. RODRIGUEZ, *Kentucky Agricultural Experiment Station, Lexington*

In previous studies on the mineral nutrition of the two-spotted spider mite, response to nutritional levels of the host plant was evaluated by introducing female mites onto isolated leaflets of tomato plants growing in the greenhouse, and counting the progeny that resulted from a given developmental period (Rodriguez 1951). While this procedure was satisfactory for utilization of tomato as the host plant, difficulties were encountered in attempts to use other hosts, such as apple, bean and rose. Moreover, the method is likely to be affected by the variable conditions of light and temperature prevalent in most greenhouses.

In our present procedure, plants are grown in the greenhouse and leaves are detached; the more critical part of the work, *viz.*, the culturing of the introduced mites on the foliage, takes place in the laboratory. The detached leaves are washed and floated in a sucrose solution or water as suggested by Yarwood (1946), who defines detached-leaf culture as "the maintaining of leaves in a living condition for various periods after detachment from the plant of which they were once a part." Leaf discs have been the most satisfactory. These are stamped out, 40 to 48 mm. in diameter, with a sharp salve-box lid, and a streak of tanglefoot is applied to the cut edge of each disc. The discs are then placed in individual petri dishes containing just enough substrate to float the discs. Substrates have included tap water and various concentrations of sucrose solutions (2, 4, and 8 per cent). Tap water was found to be a satisfactory substrate for the culture of rose, apple and tomato foliage cut in discs; these remained in perfect condition for three weeks when one longevity test was terminated. Bean-leaf discs developed roots in tap water, however; this caused water to creep over the surface of the disc. Utilization of a 2 per cent sucrose solution inhibited rooting under our test conditions for about two weeks.

Five young female mites are introduced to each disc with a fine camel's hair brush. Ten such replicates constitute a given treatment. The discs are placed on the substrate, and petri dish covers are propped open to a width of about 2 mm. to prevent fogging of the inside of the cover and resultant drip on the discs. The dishes are then distributed at random on tables over which are two adjustable banks of lights, each containing 12 slimline fluorescent tubes supplemented with 18 25-watt incandescent bulbs. This set-up can provide up to about 1000 footcandles; however, it was found that 300 footcandles is ample for the culture. This is further regulated to a daily photoperiod of 16 hours. Temperature is maintained at 26° C. ± 1°.

In preparation for counting the mites, the petri dishes containing the discs are refrigerated; this not only inactivates the mites but counting can be accomplished when it is convenient. In one test using 48 mm. bean-leaf discs cultured for 8 days under the conditions described above, one treatment (nutritional level) resulted in the following numbers of progeny of ten replicates; 212, 206, 225, 204, 232, 185, 230, 175, 215, and 178, with a mean of 206. This is a typical set of test data.

[1] The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

LITERATURE CITED

Rodriguez, J. G. 1951. The mineral nutrition of the two-spotted spider mite, *Tetranychus bimaculatus* Harvey. Ann. Ent. Soc. Am. **44**(4): 511–26.

Yarwood, C. E. 1946. Detached leaf culture. Bot. Rev. 12: 1.

Fall Armyworm Control on Late Planted Sweet Corn[1]

CHARLES H. BRETT,[2] *Raleigh, North Carolina*

The fall armyworm, *Laphygma frugiperda* (A. & S.), is one of the most destructive insects to late planted sweet corn in North Carolina. Its attacks have almost completely discouraged attempts to produce this crop after mid-summer. DDT or methoxychlor sprays in the past have shown considerable variation in their effectiveness. Injury to corn has been observed which was attributed to these sprays. This paper reports tests in which isodrin and endrin sprays were compared with DDT and methoxychlor. The isodrin and endrin emulsifiable materials contained 18.5 per cent actual insecticides. Methoxychlor and DDT materials contained 24 and 25 per cent respectively actual insecticides.

Ioana variety sweet corn was planted August 13 for this experiment. On August 19 the plants were 2 to 4 inches high and many moths were observed laying eggs. A few newly hatched larvae were present. On August 26 considerable numbers of larvae were uniformly distributed throughout the replicated plots. Spray applications were made at this time.

A second series of sprays were put on September 3rd. At this time visual scoring was made of insect injury to the plants. The least injury was in plots which had been sprayed with 4 ounces of endrin per acre. Burned spots on corn leaves indicated that some phytotoxicity had occurred from all sprays used. This appeared to increase with the amount of spray material applied.

All plots were subsequently sprayed on September 9, 16, 30 and October 7, a total of 6 weekly applications. Plant samples from each of the plots were weighed, measured for height, and per cent silking (Table 1). They were also stripped in order to determine the number of larvae present. Unfortunately, the taking of further data was prevented by a killing frost.

Untreated plants became so heavily attacked that they never reached a height of more than 10 or 12 inches. After about one month they were ragged and dying. Larval populations decreased as these plants lost their greenness and began to dry up (Table 1). By October 17, all unsprayed plants had been destroyed as can be seen in figure 1.

Plants which were more effectively protected by sprays became more attractive to the insects. Even though treated weekly, the continuous insect attack was so great that larval population counts served mostly as an index to verify that the largest and most succulent plants were the most heavily invaded. There seemed to be little control from residues. Differences in development which appeared between the treatments were not considered to be due to insect control although early larval counts indicated that endrin was the more insecticidally active of the four test materials. Treatment differences were obvious to general observation as can be seen in figure 2.

Phytotoxic effects had been easily recognized during the progress of this experiment. The end result of these effects was demonstrated in plant height, weight, and per cent of silking. This was roughly an inverse ratio with the amount of spray material used (Table 1). To better interpret this effect the same variety of corn was planted in a greenhouse in replicated plots 2 rows wide and 12 feet long. Plants were sprayed during the same stages of development and at periods of frequency which had been followed in the field. The spray treatments included some with the emulsifier materials and solvents only and some with emulsifier materials, solvents and insecticides. All of the different types of materials which had been used in the field except methoxychlor were included. The same type of burning and retarded development occurred in the greenhouse that had occurred in the field. The effect was roughly an inverse ratio with the amount of emulsifier materials and solvent applied. One of the principal solvents, xylene, appeared to be an agent in producing the effect. None of the insecticides caused any evident increase in phytotoxicity when they were included in the spray formulation.

FIG. 1.—Fall armyworm control plots. Plot on the left was sprayed with 2 ounces of endrin per acre each week for 6 weeks. Plot on the right was not treated.

SUMMARY.—The results of this experiment show DDT, methoxychlor, isodrin, and endrin sprays to be highly toxic to larvae of the fall armyworm; how-

FIG. 2. Fall armyworm control plots. Plot on the left was sprayed with 2 ounces of endrin per acre each week for 6 weeks. Plot on the right was sprayed at the same intervals with 1 pound of DDT per acre. Visual stunting of the DDT treated plants was primarily due to a greater amount of solvent being applied.

[1] Contribution from the Entomology Department. Published with the approval of the Director as paper no. 479 of the Journal Series.

[2] Associate Professor of Research in Entomology, North Carolina Agricultural Experiment Station, Raleigh, North Carolina.

Table 1.—The influence of 6 different treatments on the development of Ioana variety sweet corn attacked by larvae of the fall armyworm. Each treatment was replicated 4 times. Faison, N. C.—1952.

Material	Pounds per Acre	Average Larvae per Plant		Grams per Plant	Average Height	Per Cent Silked
		Sept. 9	Sept. 16	Sept. 24	Oct. 17	Oct. 21
Methoxychlor[1]	1.0	1.4	1.45	62.5	40.5	27.0
DDT[2]	1.0	0.85	1.18	105.9	44.5	26.0
Isodrin[3]	0.5	1.1	1.5	85.8	43.5	32.5
	0.25	0.9	1.5	110.6	49.3	42.2
Endrin[4]	0.25	0.55	1.5	122.2	41.1	49.0
	0.12	1.0	1.9	124.2	52.6	51.5
Untreated	0.0	3.17	1.6	32.0	Dead	Dead

[1] Marlate—24 per cent technical methoxychlor emulsifiable insecticide. E. I. du Pont de Nemours & Co. (Inc.).
[2] Pest-B-Gon—25 per cent technical DDT emulsifiable insecticide. California Spray Chemical Corp.
[3] Isodrin—18.5 per cent emulsifiable concentrate. Julius Hyman & Co. Division, Shell Chemical Corp.
[4] Endrin—18.5 per cent emulsifiable concentrate. Julius Hyman & Co. Division, Shell Chemical Corp.

ever, DDT and methoxychlor in order to give good control had to be used at such high rates that the solvents they were in produced an undesirable effect on plant development. Endrin was the most insecticidally active of the materials tested and was effective at application rates low enough to cause little plant damage by the solvent. Two ounces of endrin per acre at each application controlled fall armyworm sufficiently to permit good plant growth with little insect damage or phytotoxic effect.

Disinsectization of Aircraft by Lindane Vapors from Filters in the Ventilating System[1]

K. D. QUARTERMAN[2] and W. N. SULLIVAN[3]

Various formulations of pyrethrum and DDT aerosols, sometimes supplemented by the use of residual DDT deposits, have come to be accepted almost universally as the preferred method for disinsectization of aircraft as a prophylactic measure against importing vectors of disease (Duquet, 1949). However, studies conducted over the last two years (Maier *et al.*, 1953)[4] using free-flying insects in actual flight tests, have shown that aerosols containing lindane or CS-708 (Dilan) in combination with DDT (Crowell *et al.*, 1952) are considerably more effective against flies and mosquitoes than are the currently recommended formulations (Federal Security Agency 1948). Also, recent studies with lindane (Pimentel & Klock, 1953; Sullivan, 1951; Fulton *et al.*, 1952) have shown this compound to have considerable promise for aircraft disinsectization when applied either as residues or as vapors.

Preliminary tests were made in a MATS (Military Air Transport Service) Constellation at Savannah, Georgia, October 3–5, 1952, to determine whether lindane vapors dispensed from impregnated filters installed in the ventilating system (Sullivan, 1952) of large aircraft used in international traffic would serve as a practical method for disinsectization under pressurized and non-pressurized conditions.

PROCEDURE.—Free-flying laboratory-reared female house flies of the NAIDM strain were used as test insects. A 1-inch colored nylon thread was glued to the thorax of each fly (Klock *et al.*, 1953) to facilitate recovery after testing and to identify the flies used in each separate test. The 150 to 200 flies released during each test were allowed free access to all except the pilots' compartments. After a timed exposure period, the flies were recaptured as quickly as possible, removed from exposure, and offered food and water. They were then held under suitable laboratory conditions for 24-hour mortality determinations.

After an initial check test to determine that no lethal residues of insecticides were present in the plane, three glass-wool metal-framed filters were installed by bolting them over outlets in the overhead ducts of the ventilation system in the main passenger and forward navigator compartments of the plane. Each of the two filters, size 16 inches by 25 inches by 1 inch, installed in the passenger compartments had been impregnated with 100 grams of lindane from an acetone solution. The filter in the navigator's compartment was only 9 by 18 by 1 inch in size and contained 40 grams of lindane. The average air velocity through the filters during the tests was about 450 feet per minute.

Lindane samples were collected from the air in the forward and rear sections of the plane by passing a known amount of air through a 20-gram alumina column connected to a motor-vacuum pump. The lindane collected in the columns was eluted with glacial acetic acid and then determined colorimetrically (Hornstein & Sullivan, 1953).

A final hour-long test flight with the filters removed from the plane was made to determine if lethal residues of lindane had accumulated in the plane during the nine flights that were made while the filters were in place. This test was followed by an evaluation of residual lindane deposits in the plane while it was on the ground by making 1-hour exposures of flies in petri-dish wall cages (Simmons & Staff, 1945) attached to various types of surfaces in the plane. Cages were well distributed at various

[1] Through the cooperation of the U. S. Air Force, Military Air Transport Service, and numerous members of the staffs of the three participating agencies.
[2] Communicable Disease Center, Public Health Service, U. S. Dept. of Health, Education, and Welfare, Savannah, Georgia.
[3] Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, Department of Agriculture, Washington, D.C.
[4] Unpublished manuscript.

elevations from the rear to the front of the test compartments and on both vertical and horizontal surfaces. Suitable check cages were held for comparison both inside and outside of the plane.

RESULTS.—The techniques that were used for tagging and handling flies in these tests permitted an average recovery of 76 per cent of all released insects. The mortalities of check insects were low enough so that they could be eliminated from further consideration.

The initial in-flight check test of flies exposed for 60 minutes, before the lindane filters were placed in the plane, showed 0.03 micrograms of apparent lindane per liter of air and yielded a 5-per cent mortality. This test was followed by five replicates of 1-hour exposures of flies with the lindane filters in operation which resulted in an average 24-hour mortality of 99 per cent. There were no differences in fly mortalities between pressurized and non-pressurized cabin conditions. An average of 0.16 micrograms of lindane per liter of air was found in these replicates. Four additional tests in which flies were exposed for 30-minute periods produced an average fly mortality of 98 per cent and again cabin pressurization showed no effect on fly mortalities. The air in these tests contained an average of 0.09 micrograms of lindane. The final hour-long test with lindane filters removed from the plane resulted in a lindane concentration of 0.02 micrograms per liter of air, which correlated very closely with the 0.03 micrograms of lindane per liter of air found in the plane before filters were installed. However, a mortality of 97 per cent occurred among the test flies, indicating that a residual of lindane had been deposited from the vapors.

The petri-dish wall cage evaluations of residual lindane deposits in the plane clearly demonstrated that the insecticide was present in amounts sufficient to cause a 70-per cent average mortality of all the flies exposed in this manner. The mortalities ranged from 10 per cent in those flies exposed to doped fabric on the rear compartment wall to 100 per cent of those exposed to three widely separated parts of the rubber floor carpeting and to a varnished table top. Exposure to vertical varnished wood and horizontal wool surfaces also produced high mortalities. The doped fabric that covered the ceiling of the plane gave a 33 per cent average mortality.

SUMMARY.—Preliminary tests with lindane vapors from treated filters installed in the ventilation system of a Constellation airplane indicate that this method shows considerable promise for freeing aircraft of insects of public health importance. Sufficient concentrations of lindane were built up in the air and, after several tests, on resting surfaces to produce satisfactory kills of free-flying female house flies released in the plane for 30 to 60 minute exposure periods. A careful evaluation of the toxic hazards involved in such usage of lindane and developmental work to perfect this technique appear to be justified.

LITERATURE CITED

Crowell, R. L., S. L. Resnick, and R. W. Fay. 1952. Laboratory development of lindane aerosols for in-flight use in aircraft. "Proceedings"—The 38th Midyear Meeting of the Chemical Specialties Manufacturers Association, Inc.: pp. 114–7.

Duquet, J. 1949. Disinsectization of aircraft. Study made in connection with the revision of international conventions. Bul. W.H.O. 2(2): 155–91.

Federal Security Agency, U. S. Public Health Service. 1948. Foreign Quarantine Manual of Operations: pp. 13-1 to 13-5.

Fulton, R. A., R. P. Gelardo, and W. N. Sullivan. 1952. Relative efficiency of methods of applying lindane in enclosed spaces. JOUR. ECON. ENT. **45**(3): 540–1.

Hornstein, I. and W. N. Sullivan. 1953. The determination of lindane in air. Anal. Chem. 25(3): 496–8.

Klock, J. W., D. Pimental and R. L. Stenburg. 1953. A mechanical fly-tagging device. Science (in press).

Pimentel, D. and J. W. Klock. 1953. Disinsectization of aircraft by residual deposits of insecticides. Am. J. Trop. Med. Hyg. (in press).

Simmons, S. W. and Staff. 1945. Techniques and apparatus used in experimental studies on DDT as an insecticide for mosquitoes. Pub. Health Rep., Supplement No. **186**: 3–20.

Sullivan, W. N. 1951. Method of dispensing lindane vapor in air. JOUR. ECON. ENT. **44**(1): 125–6.

Sullivan, W. N. 1952. Tests with lindane vapor for freeing aircraft from insects. JOUR. ECON. ENT. **45**(3): 544–5.

FRIAR M. THOMPSON, JR. HAS ANNOUNCED THE OPENING OF AGRICULTURAL CONSULTING SERVICES SPECIALIZING IN THE DEVELOPMENT OF INSECTICIDES, FUNGICIDES, SEED DISINFECTANTS AND HERBICIDES AT 128½ COLLEGE AVENUE, ATHENS, GEORGIA.

EDITORIALS

Retirement of Dr. L. M. Peairs

The American Association of Economic Entomologists has been most fortunate through the years in obtaining the services of editors who have unselfishly, through sacrifice of themselves, carried on the work of the JOURNAL. Dr. E. P. Felt was followed by Dr. T. H. Frison who served four years, resigning in 1939 and he in turn by Dr. Leonard M. Peairs. Dr. Peairs took over the work with the beginning of Volume 33. He has been responsible for the completion of Volume 45 and will have edited four numbers of Volume 46. Failing health has been responsible for his discontinuance with the August issue and the assumption of the duties of Editor, *pro tempore*, by Dr. F. W. Poos. In an editorial in Volume 33, No. 1, the Publications Committee made the statement "The Association is again fortunate in obtaining the services of another unselfish and capable entomologist as Editor of the JOURNAL." They were correct in their estimate in both the professional capacity of the Editor and in his unselfish devotion to the cause of the Association.

L. M. Peairs was born in Lawrence, Kansas, in 1886. He graduated from the Kansas Agricultural College in 1905 and took his doctor's degree at the University of Chicago in 1925, doing his dissertation on "The Relation of Temperature to the Development of Insects" under the late E. D. Sanderson. Dr. Peairs worked in Kansas, Illinois, and Maryland as a teacher and experiment station worker then went to West Virginia in 1912 retiring from active duty there in 1952. He is the joint author with E. D. Sanderson of the second and third editions of "Insect Pests of Farm, Garden and Orchard" and later produced alone the fourth edition of this textbook. A fifth edition is expected in the spring of 1954. He has contributed numerous bulletins on economic entomology to the literature of that subject and in addition has contributed many editorials to the JOURNAL.

Aside from the two characteristics noted by the Publications Committee, Dr. L. M. Peairs is notable for his fairness. Insofar as possible, under the rules laid down by the Publications Committee and by the Association, he has always been anxious to be certain that he was fair in every detail with the authors whose papers he had for review. When there was any doubt in his mind about the quality of the paper, he referred it to several people before he arrived at a decision.

L. M. Peairs passes the torch on to Dr. F. W. Poos who will serve as Editor, *pro tempore*, for the remainder of 1953, with the assurance that the high standard maintained by Peairs and the other editors will be continued.

We know that we speak for the entire membership of the Society when we express our thanks to Dr. Peairs for his indefatigable and superior work, and the wish that he will be able to enjoy his well-earned leisure by following his hobbies that have long been neglected by reason of his long service to the Association.

C. E. PALM
E. N. CORY

The Employer's View of Entomological Training Research and Development of Insecticides

One of the main functions of a college, as I see it, is to give its graduates sufficient cultural background so that they can be readily integrated into our complex, modern society. This phase of a college education should not and cannot be overlooked by those who are guiding students in the preparation for a specific career. This subject could be elaborated considerably and has an important bearing on the Employer's View of Entomological Training especially when applied

to candidates who are being interviewed for employment whether in industry, experimental stations, or in educational institutions.

It has been aptly said that a well-trained person is one who has been schooled in fundamentals and their application to the point that he can either solve problems by reason or experimental procedure. It might be added that he should be able to communicate his findings to others in understandable language. Therefore, it cannot be too strongly stressed that for industrial as well as institutional employment, the candidate should have as broad a background as possible of fundamental or basic scientific training. It is my personal belief based on observations over the years, that many entomologists are unfortunately too narrowly trained and thus are not well-rounded professionally. This puts them at a disadvantage in intelligently comprehending the advances in closely related sciences which might be successfully adapted to use in solution of economic entomological problems or give a clearer insight into or a method of attacking problems which presently are discouraging and vexing.

It is assumed that any professional man will acquire the training necessary for the practice of his profession. It cannot be assumed that he will acquire adequate training in closely related fields to insure his comprehension of the advances in such fields and their relation and importance to his own; and in this way, broaden his outlook and opportunities. In other words. he "must avoid becoming a super specialized crank." For an entomologist he should have and can acquire a background in the fields of zoology, botany, chemistry, biochemistry and perhaps, biophysics.

ENGLISH.—Every student graduating in entomology should have sufficient training in English and at least one course in public speaking at the undergraduate level so that he can express himself clearly, accurately and concisely, both in writing and orally. Many of the controversies and disagreements—not only in science but also in all other fields of human endeavor—arise because of lack of clarity of expression and the connotation placed on or the misinterpretation of the meaning of words.

ZOOLOGY.—Too generally entomologists have only a meager knowledge of zoology of which at least academic entomology, if not economic entomology is an integral part. Irrespective of the ratio of insects to all other animals combined this might be described as a case of "the tail wagging the dog." Certainly an entomologist should have a basic and broad background in zoology particularly physiology in order to better understand what makes insects "click."

BOTANY.—What has been said about zoology applies also to botany because entomologists are largely concerned with insects affecting plants. Hence, botanical knowledge can be rightfully called a prerequisite to adequate training in entomology. Likewise in the chemical control of insects a knowledge of plant physiology is essential to the important problem of the effect of insecticides on plants just as a knowledge of human physiology is necessary to a comprehension of the findings of the toxicologist on the effects of insecticide residues on warm blooded animals.

CHEMISTRY.—Irrespective of what we may think of the place of the chemical control of insects in the ultimate scheme of things, this method of control is the quickest way known of securing at least temporary relief from the "insect menace." Speaking as an industrial entomologist, a good working knowledge of chemistry is essential to any economic entomologist and especially so to those who would work in industry. This is so because those industries employing entomologists in the largest numbers are engaged in the manufacture and development of chemical pest control agents most of which now are synthetic organic chemical compounds. Hence, in his education, the average entomologist's chemical education should extend through organic chemistry. However, should he be specializing in insect physiology or toxicology a much greater knowledge of chemistry is required.

PHYSICS.—Depending on his field of specialization, a basic knowledge of classical physics is desirable and may or may not be essential.

STATISTICS.—Since industry is finding statistics a very useful tool in many of its operations, and in many fields of biology, results are being reported in statisti-

cal terms, it follows that an entomologist cannot ignore acquiring a minimum working knowledge of the subject.

ENTOMOLOGY.—It is assumed that any student who chooses entomology as a profession will obtain as many fundamental courses in entomology as is possible without neglecting his other training. Certainly he must have general entomology as well as applied entomology. He must know insects and the basic principles of taxonomy. He should if possible, have courses in insect physiology, toxicology and research methods. In the last analysis the broader and more basic his training, the better he is fitted for whatever opportunities are open to him.

PERSONAL CHARACTERISTICS.—There are some things, however, that cannot be taught to anyone which an employer will regard equally as important as training. These are the ability of a person to fit into an organization, his adaptability, his versatility and ability to get along with others. This is because the industries which search for and develop insecticides also are developing other pesticides. Therefore, he will most certainly be in frequent contact with other biologists, chemists, physicists and engineers. Diplomacy is a valuable asset as are alertness and imagination. Summing it up, all things being equal on the basis of educational background, the candidate who has the best personality gets the job.

HARRY F. DIETZ

BOOK REVIEW

THE SOCIAL INSECTS, by O. W. Richards. Published by Philosophical Library, New York. 1953. 219 pp., 51 half tone plates and 12 text figs. $4.75.

Dr. Richards, a distinguished English entomologist who has worked for many years in the fields of insect behavior and the taxonomy of wasps and bees (to mention only some of his entomological interests!), presents here a very readable and factually accurate summary account of the social insects. In the introductory chapter a number of diverse topics which have a bearing on social life are discussed briefly, such as the senses of insects, growth, reproduction, and the various types of insect behavior. This is followed successively by chapters on the behavior of solitary and social wasps, the varieties of wasp societies, the behavior of solitary and social bees, the several kinds of social bees, ant societies, social parasites, and termite societies. In a final chapter the author discusses the problems which have to be solved in the development of a society, and contrasts insects and human societies.

KARL V. KROMBEIN

DEATHS

Notice of the death of the following members has been received:

Lt. Cmdr. Deed C. Thurman, Jr. died in Chiengmai, Thailand, on April 18, 1953, while on active duty as Malaria Control Regional Adviser with the Special Training and Economic Mission to Thailand. Mutual Security Agency.

Dr. L. B. Norton, Insecticide Chemist in the Department of Entomology at Cornell University for many years died June 10, 1953.

Professor P. J. Parrott, one of the earlier presidents of the American Association of Economic Entomologists died at Geneva, N. Y. on August 10, 1953.

It is expected to include appropriate obituary notices in a later issue.

Neale Frederick Howard
1890-1951

OBITUARIES

Neale Frederick Howard

The sudden death of Dr. Neale Frederick Howard on November 1, 1951, at Milwaukee, Wisconsin, was regretted throughout the field of economic entomology, but was felt with particular keenness in the Division of Truck Crop and Garden Insect Investigations, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

Neale Howard was born in Milwaukee, Wisconsin, on November 5, 1890, where he attended public grade and high school. He graduated from the University of Wisconsin in 1914 with a B.S. degree and in 1918 with a M.S. degree. He received his Ph.D. degree from Ohio State University in 1928.

His career of more than 33 years in entomological service started April 16, 1916, at Green Bay, Wisconsin, when he was appointed a specialist in the then Bureau of Entomology to work on the transmittal of cucumber diseases by insects. During World War I, he served as a 1st Lieutenant in the Sanitary Corps of the U. S. Army from April 1918 to August 1919. Part of this service was overseas. In November, 1919, he returned to the Bureau and was again stationed at Green Bay, Wisconsin. In March 1921, Dr. Howard was transferred to Birmingham, Alabama, to the newly established Mexican bean beetle laboratory. A short time later he was placed in charge of this work. The laboratory was moved to Columbus, Ohio, in 1926, and Dr. Howard continued in charge until ill health forced his retirement on August 31, 1949. He continued to give the Bureau the benefit of his wide experience, as a Collaborator, until his death.

The Mexican bean beetle which invaded the Eastern bean fields during the early 20's presented a serious and difficult problem. Neale Howard was among the first entomologists who investigated this problem. Work done by him and his staff on the biology, ecology, and biological control of the Mexican bean beetle resulted in lasting contributions to our knowledge of this insect. He is credited with being one of the first to test derris root powder for the control of the bean beetle. The results of his investigations with rotenone-bearing roots made a major contribution to the control of the Mexican bean beetle with this insecticide.

Although he was chiefly known for his work on the control of the Mexican bean beetle, he was extremely interested in all insect pests of vegetable crops and was quick to recognize their importance. The work at the Columbus laboratory was expanded in the late 30's to include the testing of new insecticides on other vegetable insects. His research on many of these pests resulted in important contributions to their control. Even though he was known for being conservative regarding publishing results, his research activities formed the basis for more than 60 publications.

One of Dr. Howard's outstanding attributes was his leadership ability. He was able to inspire his men and was known for being fair and just. He had a brilliant mind and was held in high esteem by his associates for his wealth of entomological knowledge and his research ability. He was truly a loyal American. A number of his former employees now hold responsible positions in entomology and related fields. They acknowledge their debt of gratitude for his guidance and deep interest in their progress during the early stages of their careers. For them, Dr. Howard's death has a deeper and more personal significance.

In religious and social affairs he was a member of the Episcopal Church, Rotary Club of Columbus, Ohio, American Legion, and was a Thirty-second Degree Scottish Rite Mason. He was a member of the American Association for the Advancement of Science, Entomological Society of America, American Association of Economic Entomologists, Ohio Academy of Science (Fellow), Columbus Entomological Society, Sigma Xi, and Gamma Sigma Delta. His avocational interests were photography, boating and St. Bernard dogs.

Dr. Howard was married to Miss Lena Shoots on June 24, 1917. He is survived by her and three sisters, Martha Howard Smith, Elizabeth Howard Richards, and Mrs. K. J. Thompson.

HORATIO C. MASON and R. H. NELSON

Perry Kips Harrison
1891-1952

Perry Kips Harrison, a long-time member of the American Association of Economic Entomologists, died on December 16, 1952 from a heart attack. He was born August 16, 1891, in Neshoba County, Mississippi, was reared on a farm and attended the public schools of his community and engaged in teaching for several years prior to entering college.

Mr. Harrison graduated from the Mobile Business College and was employed by the Louisville and Nashville Railroad at Evergreen and Montgomery, Alabama, just prior to World War I. He entered

military service in 1918 and was a member of the American Expeditionary Forces in Europe, and saw front-line duty from September 20 to November 11, 1918. Returning from the war, Mr. Harrison entered Mississippi A. & M. College (now Mississippi State College) and received his Bachelor of Science degree in 1925. He did graduate study at the University of Maryland, receiving his Master of Science degree in 1930.

During 1925–1926 he was employed by the Arizona State Department of Agriculture and served as a Quarantine Inspector at the Yuma Station. He resigned from this position and entered the service of the Bureau of Entomology and Plant Quarantine in 1926 and remained with the Bureau until he was retired October 29, 1951. During his service with the Bureau, he worked with the sweet potato weevil project in Mississippi for several years, spent some years in South Carolina, and for many years was stationed at the Louisiana State University, where he did research on cole crop insects and the sweet potato weevil.

Mr. Harrison was the author and co-author of a dozen or more circulars, leaflets, pamphlets, and bulletins—the most noteworthy of these being: "Biology and Control of the Turnip Aphid," published by the Louisiana Agricultural Experiment Station; "The Turnip Aphid," Farmer's Bulletin published by the U.S.D.A.; "A Study of Arsenical Dusting of Cabbage in Relation to Poisonous Residue." One of his most recent investigations was reported in the following paper: "Laboratory Tests of New Compounds as Insecticides Against the Sweet Potato Weevil," published in the JOURNAL OF ECONOMIC ENTOMOLOGY.

Mr. Harrison was married in 1923 to the former Vesta Gardner, who survives him. They have two sons, the older of whom is now a graduate student in Entomology at Louisiana State University. He was public spirited and interested in the various activities of his community, being a member of the Baptist Church, the National Geographic Society, The American Legion, the Baton Rouge Camellia Society, the American Association of Economic Entomologists, and a past member of the Entomological Society of America. At the time of his death, he was connected with the Louisiana State Tax Commission.

KIRBY L. COCKERHAM

William Ernest Blauvelt

Dr. William Ernest Blauvelt, professor of entomology at Cornell University and the first entomologist in New York State, to work with florist crops, died unexpectedly at his home on February 2, 1953.

Known to greenhouse operators and nurserymen throughout the country, Dr. Blauvelt was largely responsible for reducing the insect problem of florists from a Number 1 problem to one of the lesser worries.

His efforts to control spider mites began in the 1930's. Working with the systemics on the "let the plant kill the bug" theory, he developed selenium as a soil treatment at a time when nothing was better. It is still widely and effectively used.

Azobenzene developed by Dr. Blauvelt was the first successful fumigant for spider mites on roses and proved to be a lifesaver to the rose grower at the beginning of the war when labor was impossible to get. It permitted rose growers to increase production by about 25 per cent and still is frequently employed in off-crop periods.

He next shifted to phosphate materials and with Dr. Floyd Smith of the USDA he was responsible for the development of HETP, TEPP, and parathion aerosols for greenhouse use. His work in adapting parathion to greenhouse use earned him the award of the American Society of Florists in 1949.

At the time of his death, Dr. Blauvelt was at work developing combinations of insecticides that would be effective against resistant spider mites.

Dr. Blauvelt was born July 2, 1903 in Mt. Vernon, New York and was graduated from Haverstraw High School. He received a B.S. degree from Cornell in 1926 and a Ph.D. degree in 1934. After graduation he was assistant county agent in Orange County in 1927 and in Niagara County in 1928.

He returned to Cornell as extension instructor in 1928 and became an assistant professor in 1945 and a full professor in 1947.

He was a member of Alpha Zeta Fraternity and Sigma Xi and Epsilon Sigma Phi, honorary societies, and of the Entomological Society of America and the American Association of Economic Entomologists. He had been secretary and later chairman of the Extension Section of the latter group.

He is survived by his wife, Mrs. Helen H. Blauvelt; a son, Andrew Hayden Blauvelt; and two sisters Mrs. Winston Perry of Nyack and Mrs. Edward Nevins of West Nyack.

Philip Walter Berg

The following memorial was adopted at a faculty meeting at Purdue University, Lafayette, Indiana.

"In the passing of Philip Walter Berg, April 14, 1953, Purdue University and the Department of Entomology in particular lost a conscientious and loyal worker and an excellent teacher.

"Mr. Berg was born October 13, 1918, at Miles City, Montana. After graduation from the Marietta, Ohio, high school, he attended Marietta College where he received his B.A. degree in 1940. Subsequently he took graduate work at Ohio State University, University of Iowa, Wood's Hole Biological Laboratory, and Purdue University. He completed work for his M.S. degree at Purdue in 1948 and at the time of his death was completing work for his doctorate.

"Coming to Purdue for graduate work in 1946, he was counsellor at Cary Hall and graduate assistant in the Department of Entomology. In 1948 he became instructor in the Department.

"He was technical sergeant in the Malaria Survey of the Army from 1943 to 1945.

"Mr. Berg's scholastic activities and interest in science are witnessed by his membership in Phi Beta Kappa, Sigma Xi, Gamma Alpha, American Association for the Advancement of Science, Entomological Society of America, and Indiana Academy of Science. He was a member of the social fraternity Delta Upsilon.

"Philip Berg is survived by his wife, Dora Ross Berg and son, Ralph, his parents, Philip T. and Ida Wichern Berg, and a sister, Catherine Berg Semans."

The Natural Control of the Alfalfa Looper in Central California

M. PUTTARUDRIAH

Autographa californica (Speyer) is one of the many insect pests to which alfalfa, *Medicago sativa* L., a major hay crop in California is subjected. The adult is a Noctuid moth, laying eggs after dusk on the leaves; the caterpillars moving in a looping manner feed on the leaves. The pest, though seen in large numbers, has not caused any anxiety to the growers, perhaps due to the controlling action of a number of natural enemies. The object of this note is to present the results of study during 1948, regarding the extent of natural incidence and the economic importance of the various natural enemies.

Autographa californica has a characteristic "gamma" mark on the forewings with black mottlings, the hind wings being lighter. The egg stage lasts 7 days after which the larvae feed on the leaves. There are five molts with 3-day interval molts. The larvae pupate in loose white silken cocoons among leaves on the plant, the pupal period varying from 10 to 15 days. The whole life cycle from egg to adult requires 26 to 48 days.

PARASITES REARED.—The following parasites, (one dipterous and five hymenopterous) were reared from infected caterpillars collected from the fields. *Voria ruralis* Fallen, a dipterous tachinid larval parasite. *Microplitis alaskensis* Ashm., *Microplitis* sp., *Apanteles hyslopi* Vier., braconid larval parasites. *Sagaritis websteri* Vier., and *Patroclus montanus* Cresson, Ichneumonid larval and larval-pupal parasites respectively.

Many caterpillars were killed by bacterial and fungus diseases, younger instars being particularly affected. The older caterpillars when infected were not able to form healthy pupae.

INCIDENCE OF THE VARIOUS PARASITES.—From collections of caterpillars made during March to May 1948, at Tracy and Patterson, it was revealed that the total percentage of parasitism was 33.3 per cent of which the Tachinids alone accounted for 24.24 per cent, the rest constituting the Hymenopterous parasites. The incidence of parasites was higher in May in 1948 than in previous months. All stages of the caterpillars except the very young, were found parasitised. The number of Tachinid flies emerging from a caterpillar ranged from one to seven, usually 2 or 3; rarely a single fly emerging. Hymenopterous parasites were usually single on a caterpillar, but *Apanteles hyslopi* Vier., produced several to each host.

INCIDENCE OF DISEASES.—Many caterpillars died from bacterial and fungus diseases. The caterpillars attacked by bacteria turned pale white, swelled and then melted down, a foul smelling fluid oozing out from the body. The fungus infected ones showed green color at the anterior and posterior ends and were sluggish and died in 2 to 3 days. E. A. Steinhaus confirmed the presence of these diseases. He found small, gram-negative rod-shaped bacteria in the specimens not affected by fungus.

The incidence of these diseases was found to be about 40.9 per cent in the field, almost equal in extent to parasitism occurring in nature, if not greater.

Both the parasites and diseases were found to take a heavy toll of the caterpillars, to the extent of about 70 to 80 per cent, thus keeping the pest below the economic threshhold.

STAGE OF THE HOST PREFERRED BY DIFFERENT PARASITES.—All the stages of the caterpillar were preferred by the several parasites, except for *Patroclus montanus* Cresson, which oviposited in older caterpillars; the parasitised caterpillars pupated successfully, and the adult wasp emerged from the pupa.

SYMPTOMS OF THE PARASITISED CATERPILLARS.—In all cases of parasitisation, the caterpillar was found to become inactive and quit feeding; the color changed from normal green to pale white. In the case of the Tachinid fly—*Voria ruralis* Fall, small holes could be easily made out on the dorsal and lateral sides of the victim, showing where the maggots had pierced its body while entering. The holes were circular with a black scar around each of them. In advanced cases of parasitisation, puparia could be made out through the skin of the host. With some experience, host caterpillars parasitised by the Tachinid fly could be made out by the presence of the wound scars, and in later stages by the mature maggots about to pupate seen through the thin skin.

P. montanus was for the first time recorded as parasitising the late larval stage of the host, the adult parasite emerging from the host pupa. The parasitised host showed no particular symptoms, but looked healthy and pupated like the normal caterpillar. But in some cases the pupa turned darker than the normal healthy brown pupa. Otherwise it was not possible to make out the parasitisation.

The parasitic grub of *M. alaskensis*, and *Microplitis* sp., came out on the left side of the host caterpillar, near the first two pairs of prolegs, through a small circular hole which appeared as a wound scar. The parasitic cocoon was held in both cases between the middle and anal pairs of prolegs of the caterpillar, which died holding the cocoon. Sometimes it remained alive and was green in color, but unable to move. In about a day, it moved away from the cocoon and died, the color changing from green to pale brown.

ECONOMIC IMPORTANCE OF THE NATURAL ENEMIES.—Though *A. californica* is a serious pest on economic crops, it has not been a major pest on alfalfa in California, largely due to the incidence of various parasites and diseases, which take a heavy toll, to the extent of 70 to 80 per cent of the host. The incidence of the parasites was found to be 33 to 35 per cent, of which the Tachinids were 25 per cent and played a prominent part constituting an important control measure in nature.

In California, the pest was completely held in check by the natural enemies and no control measures were found necessary, and the alfalfa, a major hay crop was saved without costing the farmer anything.

The Dipterous parasite was identified by Mr. C. W. Sabrosky; the Hymenopterous parasites by Dr. C. F. W. Muesebeck; the diseased specimens were examined by Dr. E. A. Steinhaus. Dr. A. E. Michelbacher, Prof. E. O. Essig and Dr. E. A. Steinhaus gave helpful suggestions and read through the original typescript of the thesis and approved it from which this note is adopted. To all of them I am grateful.

Proposed Additions to the Common Name List, and one Change of a Common Name

On page 1114 of the December 1952 issue of the Journal of Economic Entomology 19 new names proposed for the List of Common Names of Insects and one name for which a change was proposed were published after having been approved by the Committee on Common Names. Substantial objections have been registered by members of the Society with respect to the proposed common names of *Neodiprion americanus americanus* (Leach), *N. virginiana* Roh., and *Reticulitermes flavipes* (Kollar). In accordance with established procedure, those three names are thus rejected, and the remaining names on that list are officially adopted.

The Committee on Common Names has approved proposals for the following additions to the Common Name List. Members of the Society are requested to indicate any disapproval of the present proposed additions within 30 days after receipt of the Journal, preferably by writing to the undersigned. Unless substantial reasons for disapproval are given, the additions will stand as approved by the Society.

Coleoptera

Amphimallon majalis (Raz.) ..... European chafer
Baliosus ruber (Web.) ..... basswood leaf miner
Phytodecta americana Schffr. . American aspen beetle

Lepidoptera

Aroga websteri Clarke ..... sagebrush defoliator
Caenurgina crassiuscula (Haw.) ..... clover looper
Ceratomia amyntor (Hbn.) ..... elm sphinx
Evergestis straminalis (Hbn.) ..... purple-backed cabbageworm
Lamdina fiscellaria lugubrosa (Hlst.) ..... western hemlock looper
Lamdina somniaria (Hlst.) ..... oak looper
Laspeyresia youngana (Kearft.) . . . conifer seedworm
Lithocolletis tremuloidiella (Braun) ..... aspen bloth miner
Malacosoma lutescens (N. & D.) ..... prairie tent caterpillar
Nymphalis californica (Bdv.) ..... California tortoise-shell
Spaelotis havilae (Grt.) . . western w-marked cutworm
Sphinx chersis (Hbn.) ..... great ash sphinx
Zeiraphera ratzeburgiana (Ratz.) . . . spruce tip moth

Hymenoptera

Neodiprion nanulus Schedl ..... red-pine sawfly
Neodiprion sertifer (Geoff.) . . . European pine sawfly

Arachnida

Amblyomma tuberculatum Marx . gopher-tortoise tick
Penthaleus major (Duges) ..... blue oat mite
Petrobia latens (Mull.) ..... brown wheat mite
Eotetranychus carpini borealis (Ewing) ..... yellow spider mite

A Proposed Change

Melophagus ovinus (L.) (Diptera). It has been proposed that the common name be changed from "sheep-tick" to "sheep ked," for the reason that this insect is not a true tick and that when "sheep-tick" is used an explanation is frequently necessary. True ticks also occur on sheep. "Sheep ked" is widely used abroad. Members who disapprove should register their objections in the same way as for proposed additions.

A New Edition of the Common Name List

At present the Committee hopes to publish a new addition of the Common Name List in 1954, so that it is desirable that corrections in the 1950 list and proposals which members wish to make be submitted to the Committee in 1953.

Ashley B. Gurney
U. S. Bureau of Entomology and Plant Quarantine
Washington 25, D. C.
Chairman, Committee on Common Names of Insects

The Eighth Annual Meeting of the North Central Branch of the American Association of Economic Entomologists Was Called to Order by President T. H. Parks at 10:30 A.M.

BUSINESS SESSIONS

T. H. Parks, *Presiding*
J. W. Apple, *Secretary*

First Business Session
Thursday, March 19, 1953

Report from secretary on actions taken by the Executive Committee.

The first of two Committee meetings was held December 17, 1952 at Philadelphia during the annual meeting of the A.A.E.E. Because of the tragic death of C. J. Weinman in November it was necessary for the Committee to appoint a new chairman for the Nomination Committee and an alternate to provide three members on this Committee. The Executive Committee selected A. W. Buzicky as chairman and R. H. Davidson as alternate.

The second Executive Committee meeting was held at St. Louis on March 18, 1953. At this time, the status of Branch finances was discussed and it was agreed that increased revenue should be sought from increased sales of the *Proceedings* rather than from an increase in registration fee and/or charge for *Proceedings*. During the past four years, the sale of *Proceedings* has ranged from 356 to 420 copies a year. It was felt that the sale of 100 additional copies would provide ample revenue for meeting the cost of publishing the *Proceedings* and holding the annual meeting in the manner desired by the membership. Those in attendance at the 1953 meeting were to be urged to promote the sale of *Proceedings* among members and others who were unable to attend the annual meeting.

At the 1952 meeting in St. Paul, the membership passed a resolution (No. 6) requesting the Executive Committee "to explore the possibilities of having abstracts of talks submitted in advance so that they may be assembled for distribution to the membership at the time of registration." The Committee took this suggestion under advisement but they did not feel that such a procedure was desirable because it would detract from the value of the *Proceedings*. Instead, members were notified in the program for the 1953 meeting that mimeographed summaries of their talks might be prepared for distribution during the presentation of topics.

President Parks announced that entomologists in Wyoming and Montana had indicated an interest in affiliating with the North Central States Branch of the A.A.E.E. It was moved, seconded and approved unanimously to accept the two states.

G. C. Decker, chairman of the Constitution Revision Committee, was called on to present the revised Branch constitution, the approval of which would make the organization a Branch of the newly formed Entomological Society of America. Since most members had had a chance to study the new constitution before coming to the meeting, Decker proposed that the constitution be considered as a whole and thus avoid presentation of individual sections for approval. Ray Hutson moved that we accept the constitution as written except for any sections that might be objected to in the discussion of the motion. This motion was seconded by H. A. Gunderson.

J. H. Bigger.—It is very difficult for many entomologists to choose a single interest group affiliation as proposed by the E.S.A.

G. C. Decker—This matter must be taken up with the Society. The new Branch constitution does not require that its members indicate a field of special interest for any purpose whatsoever.

No further discussion resulted so President Parks called for a vote on Hutson's motion. It passed unanimously, thus making the organization the North Central Branch of the Entomological Society of America.

Chairman Parks asked for a show of appreciation from the membership for the fine work done by the Constitution Revision Committee composed of G. C. Decker, H. M. Harris and C. E. Mickel.

Chairman Parks called on A. W. Buzicky to present the nominations for new officers of the Branch.

Chairman—G. C. Decker and C. E. Mickel
Chairman-elect—T. C. Allen and W. A. Price
Sec'y-Treas.—R. W. Rings and J. M. Wright
Representative on the Governing Board E.S.A.—R. C. Smith and J. W. Apple

Executive committee members at large—

One year—Ray Hutson and J. J. Davis
Two years—T. H. Parks and Lee Jenkins
Three years—H. M. Harris and R. E. Hill

No additional nominations were presented so Chairman Parks instructed members to cast their ballots before 6 P.M., March 19, 1953.

Chairman Parks introduced the members of the Program and Local Arrangements Committee and thanked them for their splendid work.

Program Committee
L. K. Cutkomp, *Chmn.*
E. Hixson
D. W. Hamilton

Local Arrangements Committee
Lee Jenkins, *Chmn.*
Marshall Magner
H. B. Petty
S. C. Chandler
P. C. Stone
R. E. Roselle

Chairman Parks appointed R. T. Everly as Recorder and announced his selection for the Nominating Committee for the 1954 meeting.

H. O. Deay, *Chmn.*
Fred Fletcher
Milton Sanderson

Chairman Parks requested invitations for the 1954 meeting so that they might be reviewed by the Executive Committee. Invitations were not needed for 1955 because this meeting had already been set for March 24–25 at East Lansing, Michigan.

Meeting adjourned by Chairman Parks.

BUFFET SUPPER
THURSDAY, MARCH 19, 1953

The Monsanto Chemical Company was host to those in attendance at a delightful buffet supper served in the ballroom of the Statler Hotel. The meal was followed by an entertaining and educational moving picture entitled "Sunrise Serenade" which described the mating habits of various grouse. A second picture, provided by Dr. Palm of New York, dealt with the spread and control of Dutch Elm Disease in his state.

FINAL BUSINESS SESSION
FRIDAY, MARCH 20, 1953

The meeting was called to order by Chairman Parks at 11 A.M. The chairman presented a letter from George Langford requesting advertising and subscriptions from commercial concerns for Entoma.

The chairman called for the following reports:

TREASURER'S REPORT
MARCH 26, 1952 TO MARCH 18, 1953

Credits

Balance in Treasury—March 26, 1952	$107.97
Sale of 1952 *Proceedings* at St. Paul Meeting: 299 copies @$2.00	598.00
Sale of 1952 *Proceedings* after St. Paul Meeting: 95 copies @$2.50	237.50
Sale of 19 copies of back-dated *Proceedings* @$2.00	38.00
Advance payment for 1 copy 1953 *Proceedings*	2.50
Bank interest	1.71
TOTAL	$985.68

Debits

J. H. Bigger Program Committee expenses	$ 6.00
A. W. Buzicky Local Committee expenses	2.00
Fish and Schulkamp for Fidelity Bond	10.00
J. W. Apple for St. Paul Meeting expenses	37.21
R. T. Everly for St. Paul Meeting expenses	33.78
Letter Shop for mimeographing and mailing	123.20
Branch for stamps sent as part of *Proceedings* payment	.50
Univ. of Minn. Visual Aid Service	119.97
Norma Itten for stenographic help	15.00
Cost for preparing 1952 *Proceedings*	593.34
TOTAL	$941.00
Balance on hand March 18, 1953	$ 44.68

J. W. APPLE
Secretary-Treasurer

REPORT OF AUDITING COMMITTEE

Treasurer's Report audited and found correct.
J. H. BIGGER, *Chmn.*
E. L. CHAMBERS

Treasurer's Report accepted unanimously by membership.

REPORT OF RESOLUTIONS COMMITTEE

1. WHEREAS, the program committee has arranged an interesting and instructive program which meets the requirements of both economic and basic phases of entomology, now therefore
   Be It Resolved, that the North Central Branch of the Entomological Society of America commend the excellent work done by the program committee.
2. WHEREAS, the meetings of the North Central Branch have always been characterized by informality and full discussion, as exemplified by this present session,
   Be It Resolved, that future program committees strive to the utmost to continue and encourage this ideal.
3. WHEREAS, the local arrangements committee has arranged an abundance of facilities to expedite the conduct of the meetings, particularly in the field of visual aids equipment, now therefore
   Be It Resolved, that this Branch commend the committee's efforts.
4. WHEREAS, the committee for preparing the new constitution for this Branch has discharged its duties admirably, therefore
   Be It Resolved, that the North Central Branch of the E.S.A. congratulate the committee members for their efforts.
5. WHEREAS, we have enjoyed the wonderful hospitality of the Monsanto Chemical Company at the buffet supper,
   Be It Resolved, that the members of this Branch thank the Monsanto Chemical Company for this fine evidence of friendship.
6. WHEREAS, Herbert Osborn celebrated his 97th birthday on March 19, 1953.
   Be It Resolved, that the secretary be requested to forward to Prof. Osborn this formal expression of good wishes from the North Central Branch in which Prof. Osborn has been so active, in addition to the telegram sent March 19, 1953.
7. WHEREAS, Montana and Wyoming have been accepted into the North Central Branch of the Entomological Society of America,
   Be It Resolved, that we welcome them to the fellowship and friendship of this Branch and its members.
8. WHEREAS, persistent rumors recur concerning the possible reorganization or dispersion of the U. S. Bureau of Entomology and Plant Quarantine, to the detriment of activities now in progress, therefore
   Be It Resolved, that our Secretary forward to the Secretary of Agriculture an expression of our belief that the interests of entomology and the country can best be served by the present organization of the Bureau of Entomology and Plant Quarantine.
9. WHEREAS, a great deal of confusion and anxiety surround the present lack of official status of residues on and in food products, in spite of the fact that FDA Tolerance Hearings were completed two years ago,
   Be It Resolved, that this Branch urge the establishment and formal publication of residue tolerances on and in food products before the 1954 crop season, and that the secretary forward this resolution to the Administrator of the Federal Security Agency.

J. E. BUSSART
W. W. FRANKLIN
ALVAH PETERSON
HAROLD GUNDERSON, *Chmn.*

All resolutions accepted unanimously by membership.

CHAIRMAN PARKS announced that the Executive Committee had selected Omaha, Nebraska, for the 1954 Branch meeting. Dates selected were March 25 and 26 and the Headquarters Hotel would be the Paxton. As announced earlier, the 1955 meeting will be held in East Lansing, Michigan, on March 24 and 25.

CHAIRMAN PARKS asked for a show of appreciation for the retiring Secretary-Treasurer, J. W. Apple,

who has served for seven years in this office of the Branch.

REPORT ON THE ELECTION OF OFFICERS

Chairman—G. C. DECKER
Chairman-elect—T. C. ALLEN
Sec'y-Treas.—ROY W. RINGS
Rep. to Governing Board—J. W. APPLE
Executive Committee members at large—
One year—RAY HUTSON
Two years—T. H. PARKS
Three years—H. M. HARRIS

CHAIRMAN PARKS requested the new officers to come forward whereupon he passed the direction of the Branch to the newly elected Chairman, G. C. Decker.

CHAIRMAN DECKER expressed his appreciation for the honor bestowed on him by fellow entomologists. He thanked the membership for their acceptance of the new constitution and requested that members send any proposed changes in the constitution to a committee composed of H. M. Harris, Chmn., C. E. Mickel and J. H. Bigger. Chairman Decker appointed Roscoe Hill as chairman of the Local Arrangements Committee and Harold Gunderson as chairman of the Program Committee for the 1954 meeting.

The Chairman called for new business.

J. J. DAVIS: Volume V of the Thomas Say Foundation will be available in April. This volume is entitled "Aphids of the Rocky Mountain Region" by Miss Miriam Palmer.

Please send order to me at Lafayette, Indiana. The prepaid cost is $10.25.

Meeting adjourned by Chairman Decker.

NOTES

DONALD R. JOHNSON

Donald R. Johnson of the United States Public Health Service is now back at 2271 Commonwealth Avenue, St. Paul 8, Minnesota after a two-year stay in Indonesia, to which country he was assigned by United States Technical Cooperative Administration. While in Indonesia he was connected with the Malaria Section of the Indonesian Ministry of Health, and studied the "Suspensibility of Water-dispersible Powder Concentrates Used for Malaria House-spraying Programs," because of difficulties experienced with wettable powder insecticides during his stay there. The results of his studies were printed in the Journal of the Indonesian Medical Association, Vol. 3, No. 5, 1953, under the above title.

CHANGES IN THE BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE, U. S. DEPARTMENT OF AGRICULTURE

Dr. F. C. Bishopp associated with the Bureau since 1904 resigned his position as Assistant Chief on June 30, 1953, to accept a position with the Oscar Johnston Cotton Foundation as coordinator of all Federal, State, and industry-sponsored research concerned with the control of the pink bollworm, with headquarters at Brownsville, Texas.

Dr. Edward F. Knipling replaces Dr. Bishopp as Assistant Chief in charge of Research effective July 1. Since 1946 Dr. Knipling has been Leader of the Division of Insects Affecting Man and Animals.

Dr. Arthur W. Lindquist was named Head of the Division of Insects Affecting Man and Animals effective August 1. Since 1947 Dr. Lindquist has been in charge of the laboratory at Corvallis, Oregon, headquarters for the work concerned with control of insects affecting man and animals in the Northwest.

Mr. Ralph A. Sheals, Assistant Chief in charge of Administrative Functions of the Bureau for the past 3½ years retired from Federal service on June 30. He was succeeded by Mr. Henry G. Herrell, longtime employee of the U. S. Department of Agriculture, whose appointment was effective July 1, 1953.

Mr. Eugene P. Reagan, Plant Quarantine Official of the Department since 1929, was appointed Assistant Chief in charge of Regulatory Activities of the Bureau, effective July 15. His appointment fills a post vacant since the late S. A Rohwer transferred from the Bureau in December, 1950.

Mr. E. R. Sasscer, Chief of the Division of Plant Quarantines, who has had leadership in and the responsibility for the foreign plant quarantine work since its inception in 1912 became Staff Assistant to the Chief of the Bureau on July 15, in order to permit him to devote his full time to summarizing the results of the work under the Plant Quarantine Act since 1912, and making recommendations for improving the functions authorized by that Act, and suggesting desirable changes in legislation that might make this function more effective.

Mr. Horace S. Dean, Assistant Division Leader, Division of Plant Quarantines, on July 15, 1953, became Coordinator of Plant Quarantine Operations serving under the general direction of the Assistant Chief in charge of Regulatory Activities and assisting him in administering the plant quarantine program. Mr. Dean will also serve as Air Coordinator for the Department as ARA representative on the Subcommittee on Facilitation of International Civil Aviation of the President's Air Coordinating Committee, and on other committees related to agricultural quarantine.

The functions of the Division of Plant Quarantines will be regionalized July 1, 1954.

PROCEEDINGS OF THE FIRST ANNUAL MEETING SOUTHWESTERN BRANCH

ENTOMOLOGICAL SOCIETY OF AMERICA

Galveston, Texas, February 26–27, 1953

The First Annual Meeting of the Southwestern Branch of the Entomological Society of America was held in Galveston, Texas, February 26–27, 1953.

The meeting was called to order by Chairman P. J. RENO. Following the invocation Vice-Chairman Clyde A. Bower assumed the chair and presented Mr. P. J. Reno for the annual address of the Chairman. The title of the address was "The Importance of Public Relations to Entomology."

The assembled group of 195 enjoyed invitational papers by C. E. Palm, President, Entomological Society of America, "The Challenge of the Entomological Society of America"; E. Gorton Linsley, Chairman, Division of Entomology, University of California, Berkeley, California, "Role of Basic Research in Entomology"; and E. W. Laake, Office of Foreign Agricultural Relations, Washington, D. C., "Livestock Insects and Their Control in Central and South America." Twenty-six submitted papers were presented.

An informal beach party was held on Wednesday night and a banquet on Thursday evening. Jack Criswell, National Cotton Council, acted as Toastmaster at the banquet.

Chairman Reno called for the following reports:

TREASURER'S REPORT

2-29-52	Balance on hand		$537.58
Receipts:			
2-29-52	Registration		264.00
			$801.58
Disbursements:			
	Programs	$ 40.00	
	Projector Rental	15.00	
	Badges	29.83	
	Stamps	52.82	
	Printing and supplies	144.15	
		$281.80	$281.80
Balance			$519.78

Respectfully submitted,
SHERMAN W. CLARK
Secretary-Treasurer

REPORT OF THE AUDITING COMMITTEE

We, the Auditing Committee of the Southwestern Branch, Entomological Society of America, have on this 26th day of February, 1953, examined the receipts and expenditures of the Secretary-Treasurer of the Branch and do hereby certify that said receipts and expenditures are in order.

Respectfully submitted,
C. L. SMITH, *Chairman*
GEORGE P. WENE
EDWIN J. O'NEAL

REPORT ON THE 1954 MEETING

A mail ballot was sent to the membership November 11, 1952, relative to holding a joint meeting in Dallas, Texas, with the Southern Agricultural Workers in 1954. The results of this ballot showed 109 for and 18 against. This report was accepted by the membership.

SHERMAN W. CLARK
Secretary-Treasurer

REPORT OF THE NOMINATING COMMITTEE

The nominating committee nominated officers for 1953 as follows:

Chairman: D. E. HOWELL
Vice-Chairman: DOUG EARLEY
Executive Committee: JOHN LANDRUM
Representative Board of Governors: J. C. GAINES

The membership unanimously approved the nominations.

CHANGES IN CONSTITUTION AND BY-LAWS

In accordance with proposed changes in the Constitution and By-Laws of the Southwestern Branch to conform with the new Society, the membership was circularized thirty days before this meeting relative to these changes. At the business session all changes were approved unanimously by the membership.

SHERMAN W. CLARK
Secretary-Treasurer

REPORT OF THE COMMITTEE ON RESOLUTIONS

The following resolutions were adopted by the membership:

Be it resolved that the sincere appreciation of the membership of the Southwestern Branch of the Entomological Society of America be expressed to the local arrangements committee, in cooperation with our friends of industry, for the excellent entertainment provided at the annual banquet and in the form of a beach party; to the program committee for the outstanding program presented, especially for securing the participation of the guest speakers; to Drs. C. E. Palm, E. Gorton Linsley, and E. W. Laake, for the very informative talks delivered by each; to the Galveston Chamber of Commerce for providing entertainment in the form of a tour of interesting places for the visiting ladies; to the management of the Hotel Galvez for the facilities provided for the use of the Branch in its First Annual Meeting, and to Mrs. W. C. Maxwell and Mrs. Grace Amundsen for their generous cooperation in registering members and handling the banquet tickets.

Be it further resolved that each member of the Branch make every appropriate effort to advance the cause of Entomology along the lines suggested by President Palm and Branch Chairman Reno; the secretary is hereby instructed to advise all agencies, parties or organizations included in these resolutions of the action taken.

Be it further resolved, in view of the critical pink bollworm situation, that this Branch go on record as urging continuation of an aggressive pink bollworm control program and commending the plan of the Bureau of Entomology and Plant Quarantine in cooperation with the Oscar Johnston Foundation and the Experiment Stations of all cotton growing states in their plans to expand research on the pink bollworm in an effort to establish more infallible methods of control of this insect and that the Branch Secretary be instructed to advise the Secretary of Agriculture, the Chief of the Bureau of Entomology and Plant Quarantine, the Oscar Johnston Foundation and appropriate State officials of this action.

Respectfully submitted,
L. F. CURL, *Chairman*
R. D. RADELEFF
HUGH SWINK
Resolutions Committee

MEMBERS AND GUESTS REGISTERED SOUTHWESTERN BRANCH ENTOMOLOGICAL SOCIETY OF AMERICA FEBRUARY 26–27, 1953

Acock, Robert H.
Akin, Bill
Anderson, M. L.

Barber, C. L.
Barton, Larry L.
Baskin, W. H.
Beavers, A. B.
Beckman, Herman
Becnel, I. J.
Berry, N. O.
Bieberdorf, G. A.
Bixby, A. F.
Bogaard, T. D.
Bone, Robert S.
Bottimer, L. J.
Bourland, Don T.
Bower, Clyde A.
Bramblett, W. J.
Brandes, Gordon A.
Broadus, Edward P.
Brook, Ted S.
Brooks, Fred N.
Broyhill, Roy F.
Brunn, Lynn K.
Bushland, R. C.
Bussart, J. Everett
Byrd, Felton

Carr, John B.
Cason, J. A.
Chadbourne, Dan S.
Chaney, William S.
Chase, John S.
Cherry, W. F.
Claborn, H. V.
Clark, Sherman W.
Condron, Carl H.
Cooper, James F.
Cowan, C. B.
Cowger, J. I.
Craine, Fred A.
Criswell, Jack F.
Cron, M. H.
Curl, L. F.

Daniels, Norris E.
Davis, George T., Jr.
Davis, Louis G.
Deer, James A.
Drake, Darrell C.
Dubuisson, E. B.

Earley, Doug

Fairchild, H. E.
Foster, J. W.
Fuchs, Albert
Fuller, F. M., Jr.

Gaines, J. C.
Garon, A. J., Jr.
Gibson, J. W.
Giffer, E. D.
Givens, Kenneth T.
Glick, Perry A.
Gray, Louis G.
Gregg, Paul
Gunter, Allen C.

Haberman, Warren O.
Hanna, R. L.
Hardy, W. B., Jr.
Harnden, R. C.
Harned, R. W.
Harris, Lewis P.
Hartley, R. O.
Harvey, Harry C.
Held, Bill
Hill, Lyle O.
Hillis, A. M.
Hoffman, F. C.
Hoffman, Mrs. F. C.
Hollingsworth, J. P.
Holmes, E. G
Houston, G. M
Howell, D. E
Hunt, O. E.
Hunter, George W., III

Igo, Harry
Ivy, E. E.

Jackson, J. A.
Jackson, W. S.
Jarrett, Edward S.
Johnson, Charles H.
Jones, M. P.
Jones, W. L.

Kennady, John W.
Kern, Curtis R.
King, Chas. A., Jr.
Kirkland, Jim
Kirkpatrick, W. H.

Laake, Ernest W.
Landrum, John M.
Lee, H. W.
Lett, E. R.
Lindsey, B. S.
Linsley, E. G.
Linsley, R. B.
Lloyd, Ralph R., Jr.
Lukefahr, Maurice

McAlexander, D. J.
McBride, R. M.
McCalley, Russell W.
McCulloch, George
McGregor, Ted
McGregor, W. S.
McKinney, Douglas R.
McKinney, Helen
Magner, J. M.
Maloney, Bill
Marriner, Don
Martin, Dial F.
Martin, Leo A.
Maxwell, W. C.
Meadows, C. M.
Meadows, H. E.
Melass, V. H.
Mirimanian, Miriman S.
Mistric, W. J., Jr.
Morris, J. S.
Morris, Ralph L.
Muller, George F.

Noble, L. W.

O'Neal, Jim
Orr, Guy E.

Palm, Chas. E.
Parencia, C. R.
Parker, William B.
Paul, Harry B.
Pearson, Melton T.
Peek, Carlton L.
Peterson, P. D.
Petrus, A.
Petrus, Mrs. A.
Pfrimmer, Theodore R.
Philipkoski, Stan
Pierce, Henry F.
Port, R. A.
Price, Manning A.

Radeleff, R. D.
Rainwater, C. F.
Randolph, Neal M.
Reno, P. J.
Retzloff, Al
Rider, F. L.
Riley, A. V., Jr.
Ritchie, Thomas M.
Robertson, Esco B.
Roesner, George

Schroeder, Erwin F.
Scholtz, Lenwood L.
Schwinn, David S.
Seale, Virgil L.
Sharpless, Frank T.
Simonds, James M.
Sloan, M. J.
Standish, W. L.
Starkey, Scott
Stephenson, B. C.
Smith, Charles S.
Smith, C. E.
Spicer, Wm. J.
Stroope, Don E.
Strother, Archie
Svadek, A. A.
Swan, Ogden
Swink, Hugh

Teer, Howard
Tennent, T. H.
Thomas, L. P.
Thompson, George A., Jr.
Thompson, James M.
Tillman, C. L.
Toler, I. L., Jr.
Trigg, Robert L.

Utter, L. Gordon

Wade, L. L.
Wakeman, Robert I.
Walker, W. Wayne
Wallace, D. K.
Wallace, Lee A.
Warren, R. L.
Waters, H. A.
Weaver, Nevin
Wene, George P.
White, R. W.
Williams, P. L.
Williamson, Byron
Wilson, Pat
Wipprecht, Read
Wyatt, Charles E.

Yates, Richard T.

PROCEEDINGS OF THE TWENTY-SIXTH ANNUAL MEETING

The Cotton States Branch, American Association of Economic Entomologists

Federal Building, Atlanta, Georgia February 4, 5, and 6, 1952

The twenty-sixth annual meeting of the Cotton States Branch, AAEE, was held in the Federal Building, Atlanta, Georgia, on February 4, 5, and 6, 1952. The meeting was held concurrently with the forty-ninth Annual meeting of the Association of Southern Agricultural Workers. One-hundred forty-four members registered for the meeting.

Chairman C. H. Alden opened the meeting promptly at 9:30 on the first morning. Mr. Alden was introduced by K. L. Cockerham.

Dr. E. F. Knipling, representing the Parent Association, was introduced by Mr. Alden. He reviewed the actions taken at the Cincinnati meeting. In his talk Dr. Knipling suggested that an effort be made to make the Branch meetings more interesting by widening the scope of subjects. He suggested a change in the name of Branch from "Cotton States."

The following presided over the meetings: Chairman C. H. Alden, Dr. M. D. Farrar, Mr. O. I. Snapp, Dr. F. S. Arant, and Mr. K. L. Cockerham.

Each one did an excellent job of starting the program on time, and keeping programs going smoothly. No one person presided over a session for a period of more than 2 hours at a time. Thirty-one scheduled papers were presented on the two and a half day program.

Mr. O. I. Snapp served as master of ceremonies at the Annual Entomologists Banquet which was held on Tuesday night, February 5 at the Biltmore Hotel. Members of industry contributed to the success of the banquet.

The following business was transacted at the business session:

Report of the Secretary-Treasurer

A report of the secretary-treasurer was given showing an expenditure of $41.33 and a cash balance of $667.81 was given. Motion made by O. I. Snapp and recorded by W. G. Bruce to accept the report of secretary-treasurer, subject to auditing committee report. Motion carried.

Report of the Executive Committee

Chairman Alden reported that the executive committee had agreed to abide by Memphis decision to keep the name of Cotton States Branch. Also to abide by agreement reached at Memphis meeting with regard to meeting with Southern Agricultural Workers. (This was to leave meeting place with executive committee.)

Carried over business—J. W. Wilson made motion, and seconded by Dr. Dale Newsom to resubmit to executive committee the matter of changing the name of the branch. Motion carried.

O. I. Snapp made a motion seconded by J. W. Wilson to leave to the executive committee the matter of place of meeting for 1953. Motion carried.

The following reports were submitted and approved.

Report of the Nominating Committee

Your committee proposed the following names as officers of the Cotton States Branch, AAEE, for the coming year, 1952.

Chairman, K. L. Cockerham
Vice-Chairman, A. L. Hamner
Secretary-Treasurer, L. C. Murphree

Respectfully submitted,
O. I Snapp
W. G. Bruce
M. D. Farrar, *Chairman*

Report of Auditing Committee

We, the Auditing Committee have examined the books and accounts submitted by the Secretary-Treasurer, L. C. Murphree, State College, Mississippi, for the year 1951.

The following balance is now on hand:

Checking account	$537.37
Savings account	130.44
Total	$667.81

The accounts were balanced with receipts and vouchers attached.

Respectfully submitted,
S. Marcovitch, *Chairman*
S. L. Calhoun
H. D. Purswell

Financial Statement of Cotton States Branch of AAEE February 1, 1952

Receipts
Cash

Checking account, March 20, 1951 (check from K. P. Ewing on Citizens National Bank, Waco, Texas)	$578.70
Savings account, Atlanta National Bank, Atlanta, Georgia	120.44
Total	$709.14

Disbursement

July 9, Check No. 1—50 stamped envelopes used for writing letters regarding 1952 convention	$ 1.82	
August 14, Check No. 2—360 stamped envelopes for mailing out circular letters to members in regard to 1952 convention	13.08	
September 13, Check No. 3—700 stamped envelopes for Dr. Farrar for circularizing membership in regard to 1952 convention	25.43	
September 17, postage on package of addressed envelopes to Dr. Farrar for circularizing membership in regard to 1952 convention	1.00	
TOTAL DISBURSEMENTS	$ 41.33	
Balance on hand February 1, 1952		$667.81
Distributed as follows:		
Checking account, Security State Bank, Starksville, Mississippi	$537.37	
Savings account, Atlanta National Bank, Atlanta, Georgia	130.44	
TOTAL	$667.81	

Respectfully submitted,
L. C. MURPHREE

REPORT OF RESOLUTION COMMITTEE

WHEREAS, the Cotton States Branch of AAEE has just completed its twenty-sixth annual meeting, and

WHEREAS, several persons and organizations have contributed much to the success of this fine meeting,

THEREFORE, be it resolved that the Cotton States Branch here convened in the Government Building, Atlanta, Georgia, on February 6, 1952, express thanks and appreciation to all those who have contributed to the success of the meetings and especially to the following:

To Dr. M. D. FARRAR and other members of the Program Committee who assumed extra obligations as a result of the illness of the secretary,

To Mr. W. E. BLASINGAME and other members of the committee on arrangements for their fine work,

To Mr. CECIL CLAPP of the U. S. Forestry Service for making available the room for meeting,

To Mr. STEVEN H. BEDWELL, Commodity Office of the P.M.A. for making available comfortable chairs,

To Dr. H. D. PRATT and others of the U.S.P.H.S. for providing projection equipment, arranging a tour of U.S.P.H.S. laboratories, and other cooperation,

To Mr. FRANK DANIEL of the *Atlanta Journal* for his news coverage of the meetings,

To Miss ELLEN PHILLIPS of Georgia Department of Entomology for registration of members and other fine work,

To representatives of industries for their gracious contribution to the entertainment fund,

BE IT FURTHER RESOLVED that each of these listed above be sent a copy of this resolution.

F. S. ARANT, *Chairman*
J. G. WATTS
K. L. COCKERHAM

MEMBERS AND GUESTS REGISTERED AT THE TWENTY-SIXTH ANNUAL MEETING COTTON STATES BRANCH, AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS, ATLANTA, GA. FEBRUARY 4, 5, & 6, 1952

Adair, H. S.
Alden, C. H.
Alden, John C.
Allen, Norman
Allison, F. E.

Baerman, G. D.
Bailey, F. L.
Barnes, Edward C.
Barnes, Gordon
Barnes, Ralph C.
Barron, F. R.
Becnel, I. J.
Becham, C. M.
Blake, Geo. H., Jr.
Blanton, O. H.
Blasingame, W. E.
Boland, E. P.
Brauch, C. B.
Brogdon, James E.
Brunn, Lynn K.
Bruce, W. G.
Burgess, Robert W.
Burnett, Glenn

Calhoun, S. L.
Campbell, W. V.
Cassidy, T. P.
Chamberlain, W. F.
Chase, Ronald R.
Cochran, J. H.
Coe, Ed H.
Cokerham, K. L.
Compton, C. C.
Conner, J. T.
Cook, S. E.
Crutchfield, C. M.

Darley, M. M.
Davis, Claude T.
Dunavan, David
Downey, Norman R.
Dilworth, Hal C.
Dupree, Minter
Dye, H. W.

Easley, Tildon
Eden, W. H.
Elmer, Howard

Farrar, M. D.
Feistner, Wm. E.
Ferguson, Paul
Fife, L. C.
Fletcher, Orlin K., Jr.
Fletcher, Fred
Floyd, E. H.
Fritz, Roy F.

Galloway, A. L.
Gerboldt, C. E.
Girardeau, J. H.
Good, Newell E.
Green, H. B.
Griffin, James
Guyton, F. E.

Hamman, Robert
Hamner, A. L.
Harrison, James A.
Heinel, Arthur
Hode, C. R.
Hutchens, R. E.

Jarnagin, W. M.
Johnson, Conrad C.
Johnson, W. C.
Johnston, H. R.
Jones, M. P.
Jordan, C. R.

Kelsheimer, E. G.
Kulash, W. M.

Lattue, D. W.
Leonard, G. F.
Lindaberry, H. L.
Littig, Kent S.
Lloyd, Ralph R.
Lund, H. O.
Lyle, Clay

McGa, Martell
McMurry, J. F.
Magner, J. M.
Manghan, D. B.
Markel, Edward P.
Maxwell, J. M.

Mayeaux, Herman S.
Miller, John M.
Moore, John E.
Moore, L. H.
Morgan, L. W.

Neely, J. F.
Nettles, W. C.
Newman, M. G.
Newson, L. D.

Parkinson, K. R.
Paul, J. J.
Popham, W. P.
Pratt, Harry
Purser, W. H.

Purswell, H. D.

Quisenberry, B. F.

Ray, Augustine
Reed, J. K.
Richie, T. M.
Ritcher, Paul O.
Rohwer, G. G.

Schoof, H. F.
Secrest, H. C.
Selby, J. W., Jr.
Sharpless, F. T.
Smipling, E. F.
Smith, Clyde F.
Snapp, Oliver I.
Snipes, B. Thomas
Sparks, L. M.
Spears, R. K., Jr.
Stanley, W. W.
Stayner, L. F.
Steinhauer, C. J.
Stetile, Jno. J.
Stripling, Earl L.

Tissot, A. N.
Todd, J. N.
True, H. H.
Turner, Henry
Turnipseed, G. F.

Upholt, William

Wagner, W. E.
Walker, R. L.
Watts, J. G.
Weil, A. E.
White, J. F.
Williams, Francis J.
Williams, Jerry A.
Williams, Ralph E.
Wilson, C. A.
Wilson, John W.
Woodburry, E. N.

Yates, Richard T.
Youngblood, Neil W.

PROCEEDINGS OF THE TWENTY-SEVENTH ANNUAL MEETING

THE COTTON STATES BRANCH, ENTOMOLOGICAL SOCIETY OF AMERICA

Jung Hotel—New Orleans, La. February 9, 10, 11, 1953

The twenty-seventh annual meeting of the Cotton States Branch ESA was held in the Jung Hotel, New Orleans, Louisiana, on February 9, 10, and 11, 1953. The meeting was held concurrently with the fiftieth anniversary of the Association of Southern Agricultural Workers.

One hundred and sixty-four members registered for the 3 day meeting.

Chairman K. L. Cockerham opened the meeting promptly at 9:15 A.M. The minutes of the last meeting and the report of the secretary-treasurer were approved as read.

Vice-Chairman A. L. Hamner assumed the chair and presented Chairman Cockerham for the annual address of the Chairman. The title of the address was "A Plea for a Return to Fundamental Research in Entomology."

Dr. Charles E. Palm, President of ESA, represented the parent association at the meeting. In his address he congratulated the Cotton States Branch for the honor of holding the first branch meeting of the new Entomological Society of America. Dr. Palm discussed "The Broad Challenge that Entomology Offers Today."

Chairman Cockerham appointed the following committees:

Nomination—C. F. SMITH, J. W. WILSON, and CHARLES LINCOLN, *Chairman*
Auditing—ROSS E. HUTCHINS, W. J. EDEN, and R. J. KOWAL, *Chairman*
Resolutions—W. W. STANLEY, A. N. TISSOTT, and C. M. BECKAM, *Chairman*

Fifty-three papers were presented during the 3-day meeting covering a wide variety of work being carried on within the area covered by the Cotton States Branch ESA.

The following presided over the paper reading sessions:

Chairman K. L. COCKERHAM, A. L. HAMNER, R. C. GAINES, CLAY LYLE, C. E. SMITH, C. H. ALDEN, E. W. DUNNAM and J. W. INGRAM.

The program committee was composed of F. S. ARANT, C. H. BRADLEY, and L. D. NEWSOM.

The local arrangements committee was composed of L. J. BECNEL, A. L. DUGAS and EDWIN LOTT.

In the business session, the following business was approved:

REPORT OF THE SECRETARY-TREASURER

The Secretary's report showed a membership of 447 members of the AMERICAN ASSOCIATION of ECONOMIC ENTOMOLOGISTS and 43 members of the ENTOMOLOGICAL SOCIETY OF AMERICA residing in the area covered by the COTTON STATES BRANCH. Notice of the twenty-seventh annual meeting was sent to 490 members of the ENTOMOLOGICAL SOCIETY OF AMERICA residing within the Cotton States Branch territory.

FINANCIAL STATEMENT OF COTTON STATES BRANCH ESA, FEBRUARY 5, 1953,

Balance on hand February 1, 1952		$667.81
Receipts:		
Interest—Savings account, Atlanta National Bank, Atlanta, Georgia, February 3, 1953		2.61
Registration Fees—144 members	$144.00	
Contributions—Balance from Banquet	17.35	$161.35
		$831.67

Disbursement:

Feb. 4, 1952—C. H. Alden (expenses for 1952 membership meeting)	$ 60.00	
Feb. 7, 1952—Chambers Printing Co. 1952 program printing	68.71	
Postage—Membership correspondence (two circular letters)	37.50	
A. L. Hamner, Partial expenses to 1952 meeting—acting secretary	22.81	
Jan. 24, 1953—Baton Rouge Printing Co.—1953 program printing	94.86	
Jan. 25, 1953—Delta Press—Printing registration cards	4.33	
TOTAL EXPENSES	$288.21	
Balance on hand February 5, 1953		$543.46

Distributed as follows:

Checking account, Security State Bank, Starkville, Mississippi	$410.41	
Savings account, Atlanta National Bank, Atlanta, Ga. (letter attached)	133.05	
TOTAL	$543.46	

Respectfully submitted,
L. C. MURPHREE, *Secretary-Treasurer*

REPORT OF EXECUTIVE COMMITTEE

Chairman Cockerham reported that the executive committee met on February 9, 1953 with 9 members present. They made the following recommendations:

That a resolution be passed to meet with the ASSOCIATION OF SOUTHERN AGRICULTURAL WORKERS and register with them, but reserve the right to meet separately when they meet out of our territory, or when we wish to meet with the ENTOMOLOGICAL SOCIETY OF AMERICA, if it meets within our territory.

Recommended to withhold any action on change of name of COTTON STATES BRANCH until a committee of parent association made a study on redistricting and renaming branch section.

Both recommendations were approved.

REPORT OF AUDITING COMMITTEE

We, the auditing committee, have examined the books and accounts submitted by the *Secretary-Treasurer*, L. C. MURPHREE, *State College, Mississippi*, for the year 1952. The following is now on hand:

Checking account	$410.41
Savings account	133.05
TOTAL	$543.46

The accounts are balanced with receipts and vouchers attached.

Respectfully submitted,
R. E. HUTCHINS
R. J. KOWAL
W. J. EDEN

REPORT OF RESOLUTIONS COMMITTEE

WHEREAS, several persons and organizations have contributed much to the success of this fine meeting.

THEREFORE, be it resolved that the COTTON STATES BRANCH here convened in the Jung Hotel, New Orleans, Louisiana, on February 11, 1953 express thanks and appreciation to all those who have contributed to the success of the meeting and especially to the following:

To Mr. Kirby L. Cockerham for his interest and untiring efforts in serving as Chairman, COTTON STATES BRANCH, during the past year,

To Dr. L. D. Newsom and other members of the Program Committee for arranging a splendid program,

To Mr. Edwin Lott and other members of the committee on arrangements for their fine work,

To the management, Jung Hotel, for making available the Cotillion Room for the meeting,

To Mr. B. B. Jones, Secretary-Treasurer, Association of Southern Agricultural Workers, for cooperation in arranging the annual meeting,

To the Coahoma Chemical Company, Clarksdale, Mississippi, who: (1) furnished stenographic help for the Secretary, mimeographing, paper, and telephone calls, (2) paid secretary's expenses to meeting, (3) offered to send stenographer to meeting if needed,

To representatives of industry for their gracious contribution to the entertainment fund.

WHEREAS, Mr. Oliver I. Snapp has prepared the record of *Southern Entomology* in "*The South on the March*," a History of the Association of Southern Agricultural Workers commemorating the Golden Anniversary of this organization, which shows the progress that entomology has made in the South during the past 50 years,

THEREFORE, be it resolved that the COTTON STATES BRANCH express thanks and appreciation for this excellent history.

WHEREAS, the COTTON STATES BRANCH of the Entomological Society of America has just completed its twenty-seventh annual meeting, and

WHEREAS, the pink bollworm continues to spread and is an increasing threat to the cotton industry, be it resolved that the states of Arizona, New Mexico, Oklahoma, Louisiana and Texas be urged to continue a full scale cooperative program with the U. S. Bureau of Entomology and Plant Quarantine to control the pink bollworm and prevent its further spread through the exercise of every means available including mandatory cultural controls, appropriate treatment of lint cotton, cotton seed and other products capable of disseminating the pink bollworm, and sanitation at gins including burning, grinding or composting of gin trash and burrs. The pink bollworm cooperative work in Mexico should be continued by the U. S. Bureau of Entomology and Plant Quarantine in order to secure comparable regulatory and control program in Mexico which will benefit the American cotton producer.

The action taken recently by non-infested states to implement the present control program by establishing quarantine stations on the Texas line on roads entering Oklahoma, Arkansas, and Louisiana is vitally essential since inspection of vehicular traffic leaving Texas in the fall of 1952 resulted in

interception of numerous lots of infested cotton bolls and seed cotton. Since the funds now available to the U. S. Bureau of Entomology and Plant Quarantine are required for the essential regulatory, inspection and control program, already under way, any financial participation of the Bureau in through-vehicular inspection on the Texas line should be provided for by additional funds to be made available for the purpose over and above current or anticipated funds available.

Be it further resolved that the Bureau of Entomology and Plant Quarantine be urged to continue the Wild Cotton Eradication Program in southern Florida since experience indicates that if the pink bollworm builds up in the wild cotton it is capable of spreading into Georgia by natural means as happened in 1933 before the program had reduced pink bollworm population in the wild cotton in southern Florida.

Be it further resolved that, the Bureau of Entomology and Plant Quarantine and the Experiment Stations of the pink bollworm infested states be commended for the action taken to expand pink bollworm research in an effort to secure new information to aid in the control of this insect. The action of the Oscar Johnston Foundation in allotting funds for pink bollworm is highly commended. It is urged that the non-infested states likewise give careful consideration to entering into active participation in the research by providing additional personnel or funds.

Be it further resolved that the Secretary be instructed to furnish copies of this resolution to—the Secretary of the United States Department of Agriculture; Chief, Bureau of Entomology and Plant Quarantine; the Experiment Station Directors; Commissioners of Agriculture; Plant Quarantine Officials; Governors; Senators and Representatives of every cotton producing state from Virginia on the east to California on the west.

Whereas insects and other agricultural pests are continually changing; be it resolved that because of the continued need for high production of food, feed and fiber crops and protection of man and animals from insects and related pests, the cooperative program established to provide information on pest conditions be continued, and expanded where warranted, to aid American farmers, agricultural workers and industry.

BE IT FURTHER RESOLVED that the Secretary be instructed to send copies of these resolutions to the persons and organizations concerned.

C. M. BECKHAM, *Chairman*
W. W. STANLEY
A. N. TISSOT

REPORT OF NOMINATING COMMITTEE

The nominating committee wishes to make the following nomination for officers of the COTTON STATES BRANCH of the ENTOMOLOGICAL SOCIETY OF AMERICA:

For *Chairman*—F. S. ARANT
For *Vice-Chairman*—H. C. YOUNG
For *Representative on Governing Board of ESA*—M. D. FARRAR
For SECRETARY-TREASURER—L. C. MURPHREE

Submitted by Nominating Committee
C. F. SMITH
JOHN W. WILSON
CHARLES LINCOLN, *Chairman*

A motion was made and seconded that a fund of $150.00 be set aside for travel expense of the Branch representatives on the Governing Board of ESA to official meetings.

This was amended and approved to allow per diem expenses that are not otherwise covered for Branch Representative on Governing Board of ESA for official meetings.

The meeting adjourned at 10:45 A.M. following the final business session.

Respectfully submitted
L. C. MURPHREE
Secretary-Treasurer

MEMBERS AND GUESTS REGISTERED AT THE TWENTY-SEVENTH ANNUAL MEETING COTTON STATES BRANCH, ESA, NEW ORLEANS, LA., FEB. 9, 10, 11, 1953

Akin, Bill
Alden, Chas. H.
Alden, John C.
Allen, Norman
Anderson, M. L.
Armstrong, G. B.
Arthur, B. W.
Avant, F. G.

Bailey, Horace L.
Baker, W. A.
Barron, F. Ray
Bartlett, F. J.
Beckham, C. M.
Becnel, I. J.
Bennett, A. G.
Bewick, L. F.
Bick, Geo. H.
Bondrean, H. B.
Boren, R. B.
Both, R. J.
Brandon, Gordon H.
Brazzel, J. R.
Broadus, E. P.
Brown, James L.
Bruce, W. G.
Brunn, L. K.
Burns, E. C.
Bussart, J. Everett
Byrd, Felton

Calhoun, S. L.
Chamberlin, F. L.
Chandler, S. C.
Charpentier, Leon J.
Chase, R. R.
Cockerham, K. L.
Cochran, Raymond H.
Conner, James T.
Cottier, E. F.
Cotton, R. T.
Cowart, L. E.
Coyne, J. F.
Crigler, J. L.
Curl, L. F.

Day, Augustine
Dilworth, Hal C.
Dixon, R. E.
Dodge, H. H.
Dorward, Kelvin
Douglas, W. A.
Downey, Norman R.
Dugas, A. L.
Dunnam, E. W.
Dupree, Minter

Eden, W. G.
Eddy, C. O.
Edwards, L. V.
Elmer, Howard
Ernest, H. A.

Fallon, L. C.
Fancher, C. C.
Farrar, M. D.
Fife, L. C.
Fitzgerald, F. M.
Fletcher, Fred
Floyd, E. H.
Fritz, Roy F.
Gaines, J. C.
Gaines, R. C.
Galloway, A. L.
Green, H. B.
Griffin, J. A.

Hamner, A. L.
Hatcher, R. F.
Helm, R. W.
Hensley, Wm. A.
Hutchins, R. E.
Hyche, L. L.

Iglimsky, W., Jr.
Ingram, J. W.

Jarnagin, W. M.
Johnson, H. S., Jr.
Johnson, W. C.
Jones, M. P.
Jordan, C. R.

Kamal, M.
Keller, John C.

Kelsheimer, E. G.
Kirkland, Robert O.
Kowal, R. J.

LaHue, Delmon W.
Lanier, James A.
Latta, Randall
Lee, R. E.
Linealn, Charles
Lloyd, Ralph R., Jr.
Lott, Edwin R.
Lyle, Clay

McCrory, S. G.
McIntiry, W. H.
McPherson, T. O.
Magner, J. M.
Majeux, Herman S.
Marlan, W. L.
Mason, Curtis L.
Mathes, Ralph
Mauldin, C. B.
Merkl, M. E.
Meek, Roy
Miller, Edward R.
Mitchell, Bruce
Moore, L. H.
Mullett, R. P.
Murphree, L. C.

Newsom, L. D.
Norris, A. L.

Oertel, E.
Ohwein, H. P.

Palm, C. E.
Patton, Don
Paulson, C. A. Paul
Penn, Geo. H.
Pierce, W. C.
Purswell, H. D.

Quisenberry, B. F.

Reed, L. R.
Reno, P. L.
Riley, A. V., Jr.
Ritchie, T. M.
Roberts, J. H.
Robertson, R. L.
Rogers, W. C.
Rosewall, O. W.
Roussel, John S.

Schoof, H. F.
Secrest, H. C.
Selby, J. W., Jr.
Sharpless, F. T.
Shields, Dalton
Sloan, M. J.
Smith, C. E.
Smith, Clyde F.
Smith, L. G.
Smith, R. J., Jr.
Smith, R. H.
Smith, W. R.
Snipes, B. Thomas
Stanley, W. W.
Stiles, C. F.
Swink, Hugh

Thames, Walter H., Jr.
Tissot, A. N.

Whamond, H. O.
White, J. F.
White, R. W.
Whitefield, D. A.
Williams, Ralph E.
Wilson, C. A.
Wilson, John W.
Woodbury, E. N.
Wylie, W. D.

Young, Herman C.

MINUTES OF THE SEVENTEENTH MEETING

GEORGIA ENTOMOLOGICAL SOCIETY

Dempsey Hotel, Macon, Georgia
March 6–7, 1953

The meeting was called to order by President W. F. Turner at 1:00 P.M. Mr. Tom Duck introduced Mayor Lewis B. Wilson of Macon, who welcomed the Society to Macon. President Turner thanked Mayor Wilson for his cordial welcome.

In his presidential address, Mr. Turner pointed out the many advantages of Statewide over national or regional meetings and expressed his confidence in the continued rapid growth of the society. He pointed out that one of our obvious weaknesses at present is our failure to interest more amateur entomologists. He suggested that future officers concern themselves with this problem.

Mr. F. E. Allison, membership committee chairman, introduced the 26 new members and Mr. G. G. Rohwer presented items of interest (personal and professional) concerning various Society members.

Mr. G. G. Rohwer then introduced Dr. Randall Latta, In Charge, Division of Stored Product Insect Investigations, who brought greetings from the Bureau of Entomology and Plant Quarantine. He outlined the reorganization of the Research Divisions of the Bureau and indicated the lines of work that will receive increased emphasis.

The minutes of the last meeting were then read and approved.

President Turner then called for the report of the Secretary-Treasurer which read as follows:

As of March 5, 1953, the Georgia Entomological Society has an active membership of 117. Copies of the minutes of the Savannah meeting in 1952 were sent to 125 interested entomologists and a rather full statement of the proceedings was published in the JOURNAL OF ECONOMIC ENTOMOLOGY. 150 preliminary announcements and programs of the 1953 meeting were sent out.

O. I. Snapp concluded for the Publications Committee that the publication of either a periodical or of occasional papers on the insect fauna of Georgia seemed impractical at present and recommended that the question of a Society publication be temporarily tabled. He reported that he had contributed a write-up on the Georgia Entomological Society to *The South on the March*, a publication sponsored by the Association of Southern Agricultural Workers.

The new Constitution and By-Laws were adopted by a unanimous vote. Mr. Snapp rose to compliment the Committee on Revision of the Constitution, consisting of G. G. Rohwer, C. M. Beckham, and H. O. Lund.

It was moved and adopted that the incoming president appoint a committee to study the possibility of the Society's sponsoring a scholarship for the study of entomology and to present at the next meeting a plan for administering such a scholarship, if the committee was disposed favorably toward such a move.

On motion, approved, the secretary was instructed to poll the members in regard to the preferred time of week for holding the meetings and also on the length of the program.

On motion approved, the incoming officers were instructed to continue to solicit membership and participation in the program from industry. On call from President Turner, 17 members of industry rose and were introduced.

On motion, Prof. G. L. Carver, Mercer University, was invited to speak to the group at the end of the paper-reading session.

H. O. Lund invited the Society to hold its next meeting at the University of Georgia in Athens. The invitation was accepted by unanimous vote.

The following committees were appointed:

Resolutions: F. E. ALLISON, H. N. POLLARD, G. W. R. DAVIDSON

Auditing: TOM DUCK, JOHN BURNETT, HAROLD HAYES

Nominating: G. G. ROHWER, C. H. ALDEN, JOHN ALDEN

The paper-reading sessions followed:

1. F. S. Chamberlin, B.E.P.Q., Quincy, Fla., described "The Coöperative Economic Insect Report," objectives of which are the stimulation, collection, and distribution of information needed in the control of insect pests. The data taken in each State are sent to the respective state clearing house, following which it is forwarded to the Washington office to be included in the weekly National Report. All entomologists were urged to give this effort their full support.

2. C. R. Jordan, University of Ga., Athens, spoke on the "Insect Pest Reporting Service in Georgia." He recalled several instances in which an early knowledge of pests gained from the Reporting Service enabled him to get control information into the hands of County Agents before they received their first complaints.

3. O. I. Snapp, B.E.P.Q., Fort Valley, discussed his "Peach Insect Control Experiments in 1952" in which he found that aldrin worked into the soil at rates as low as 2 pounds per acre was highly effective against the plum curculio during its immature stages and dieldrin was fairly effective. Parathion and EPN were more effective in preventing oriental fruit moth injury and aldrin and dieldrin were less effective against that insect than other materials. Methoxychlor and lead arsenate were intermediate in effectiveness against the oriental fruit moth. Dilute liquid spray[1] applied with a mist blower for plum curculio and oriental fruit moth control. Parathion was more effective than DDT or benzene hexachloride for preventing infestation of peach trees with the lesser peach tree borer. Ethylene dichloride emulsion was highly effective as a fumigant treatment for peach tree borer control without injuring the trees. Trichlorobenzene emulsion and paradichlorobenzene crystals also gave excellent results for peach tree borer control. Benzene hexachloride and parathion as trunk sprays gave good results in preventing infestation by the peach tree borer.

4. Mintor Dupree and C. M. Beckham, Ga. Expt. Sta., Experiment, Ga., summarized "A Two-Year Study of Insecticides for Control of the Pecan Weevil," as follows: The weight of sound nuts produced per tree showed the insecticides ranked in the following order of effectiveness: DDT and parathion combined, dieldrin, DDT alone, and toxaphene. Jarring records of the number of weevils present in the trees following spray applications show DDT, dieldrin, and DDT-parathion combined about equal in effectiveness. Considerably more live weevils were jarred from the toxaphene treated trees. Although the numbers of spider mites were not unusually high, parathion added to DDT spray considerably reduced the population of this pest. The peak of weevil emergence occurred during the last week of August and the first week of September, which indicated that spraying need not begin prior to this time in the Piedmont section of Georgia.

5. Max R. Osburn, B.E.P.Q., Albany, found in his "Experiments for Control of the Hickory Shuckworm" that early and midseason sprays of EPN (2 lbs. of wettable powder to 100 gallons of water) applied before the shell hardening period, reduced the dropping of immature nuts but had no effect on the percentage of nuts infested with shuckworm. Three late applications controlled the shuckworm in pecan shucks better than three early applications and just as well as three early and three late or even as nine applications. The quality of nuts also was superior in all those plots receiving the late treatments. Late applications also controlled the black pecan aphid and the mite, *Tetranychus hicoriae* (McGregor).

[1] Was more effective than concentrated spray.

6. H. N. Pollard, B.E.P.Q., Fort Valley, reported the "Apparent Establishment of a Southwestern Leafhopper in Middle Georgia." *Homalodisca insolita* (Walker) was observed in 1950, 1951, and early 1952 in a restricted area. By later 1952, however, the infestation had expanded considerably. Although tests indicate its ability to transmit phony disease of peaches, preliminary life-history studies indicate that it is graminicolous and therefore not likely to develop into a significant vector in nature.

7. J. H. Girardeau, Jr., Coastal Plain Exp. Sta., Tifton, spoke on "The Present Status of Planned Pollination in Georgia." He pointed out that despite difficulties encountered at harvest, and despite the lack of suitable rental agreements planned pollination is growing in Georgia. In one clover field of 90 acres, the increase of seed harvested under adverse conditions produced at least $2,000.00 worth of additional seed due to the presence of honeybee colonies. The honey value was about $200.00.

8. G. L. Carver, Mercer University, Macon, then spoke briefly on the subject of Conservation.

9. The afternoon session closed with the showing of the Hercules Powder Co. film, "Pollination of Alfalfa" by R. R. Chase, Hercules Powder Co., Atlanta.

A Hospitality Hour from 7:00 to 8:00 P.M. in the Pinebrook Inn through the courtesy of the Insecticide Industry was followed by the annual banquet, which was attended by 116 persons. C. H. Alden, State Entomologist, Atlanta, served as toast master and entertainment was provided by the Triangle Chemical Company of Macon.

The Saturday morning session resumed at 9:00 A.M. with a panel discussion on "Quarantines and Plant Regulations" moderated by C. H. Alden, who discussed the general features of Georgia quarantines and the more specific problems with the pink bollworm and the Japanese beetle.

G. G. Rohwer stated that infestations of white fringed beetle occur in 53 counties, infestations having been eradicated in 27 localities. He described the general control program. J. E. Burnett, Eastman, stated that a surface application in dilute emulsion of five pounds of dieldrin per acre apparently cleared up an infestation averaging 50 grubs per square yard at Hawkinsville, Ga. O. W. Whitehead, Statesboro, described very promising tests with granulated DDT and dieldrin in Evans Co., Ga.

F. R. Blackwell, B.E.P.Q., Tifton, reported a 94 per cent reduction in properties infested by the sweet-potato weevil since 1945. Only 95 properties in ten counties remain infested of 1,163 in 31 counties found infested since 1945.

T. D. Persons, Macon, stated that of two million peach trees inspected in 1952 for phony disease, 91,000 or 4.8 per cent were infected. Plum (reservoir host for virus) surveys were made in 89 counties in 16 states, with positive findings in 21 counties in 10 states.

10. The second paper-reading session began with a description of the "Role of Entomologists on International Health Programs" by H. D. Pratt, U.S.P.H.S., Chamblee. He pointed out that the work of the public health entomologist falls into four major categories: promotional, operational, training and research. Each of these types of work was discussed and illustrated by kodachrome slides taken in the West Indies or Southeast Asia.

11. R. E. Fritz, U.S.P.H.S., Atlanta, and H. D. Pratt discussed the "Present Status of the More Important Arthropod-borne Diseases in the U. S." They listed 7,635 reported cases of malaria in 1952, 743 cases of virus encephalitis, 186 cases of endemic typhus, 316 cases of spotted fever, 666 cases of tularemia, and (in 1951) 7 cases of plague.

12. H. R. Dodge and J. M. Seago, U.S.P.H.S., Chamblee, reported on the "Sarcophagidae and Other Diptera Taken by Trap and Net on Georgia Mountain Summits in 1952." On eleven summits in North Georgia from May 2 to Nov. 17, 20,811 flies were taken in traps, 6,669 by net. Sixty-four species of Sarcophagidae were taken by net, only 41 from traps. Thirty-four species were taken only by net, probably 15 or more being new species. The total number of species taken is 75.

Trapped specimens were mostly females of saprophytic Sarcophagidae, Muscidae, and Calliphoridae. Netted specimens were mostly males of species whose larvae are believed to be parasitic.

13. R. A. Moncrief, Ass't. State Chemist, Atlanta, spoke on "The Georgia Economic Poisons Law," which he stated was one of the best "uniform acts" in the U. S. He pledged the co"peration of his office with the entomologists of the State.

14. L. W. Morgan, Coastal Plain Exp. Sta., Tifton, described the "Control of Insects Attacking Peanuts." He considers cutworms, thrips, fall armyworm, velvet-bean caterpillars, corn earworms, lesser cornstalk borer, and the rednecked peanut worm to be some of the worst pests.

15. J. J. Paul, Univ. of Ga., Athens, discussed "Poisons for Pests of Ornamentals." He listed the factors influencing the toxicity of a chemical to plants as well as to animals. Parathion appears to be safe for ornamentals generally. Except for a few individual plant species, most chlorinated hydrocarbons are safe. Most miticides, however, tend to be phytotoxic but EPN, DMC, and Aramite are quite safe.

16. F. A. Morton, Headquarters Third Army, Fort McPherson, in his discussion of the "Control of Insects and Fungi in Lumber and Wood Products" stated that the cost of repairing damage inflicted by termites and decay organisms has increased greatly in recent years due to the increased use of non-resistant sapwood lumber, and to the rising costs of lumber and labor for replacement.

The Third Army area includes seven southeastern states where the high annual temperatures and high rainfall rates are favorable to termite and decay organisms. The known cost of termite and decay damage at Third Army Installations during Fiscal Year 1951 and Fiscal Year 1952 amounted to approximately $13,000,000. Steps taken during Fiscal Year 1951 and Fiscal Year 1952 to reduce future maintenance costs included the use of better construction methods, the use of 14,000,000 board feet of treated lumber, and extensive soil poisoning operations for termite control. On a 20-year basis, it is estimated that approximately $40.00 will be saved in future maintenance costs for each $1.00 spent for the preservative treatment of any lumber that will be exposed to termite and decay hazard. The additional cost for the 14,000,000 board feet of treated lumber used was approximately $560,000, and it is estimated that this will result in a long-term saving of approximately $21,840,000. Extensive treatments were made to control powder post beetles in brooms, tool handles, hardwood cots, storage pallets, and similar items.

17. T. M. Gunn, Orkin Exterminating Company, Atlanta, spoke on "Entomology and Commercial Pest Control." He cited examples of whole new fields in which pest control operations were developing and urged the training of more personnel in sound basic entomology and toxicology to enable the industry to meet these needs in a creditably professional manner.

18. W. H. Cross, University of Ga., Athens, discussed "The Use of Light Traps for Analyzing Insect Populations." Bar graphs of samples collected in an open-funnel trap in Aiken County, S. C., between March 25 and November 14, 1952, showed that the different orders exhibited two or three more or less simultaneous peaks of abundance which corresponded in most cases to fluctuations in temperature and other weather conditions.

At the close of the final Business Meeting the Nominating Committee recommended the following: for president, W. E. Blasingame; for vice-president, F. E. Allison. The secretary was instructed on motion to cast a unanimous ballot for these nominees.

A total of 78 members and guests registered at the meeting.

HORACE O. LUND
Secretary-Treasurer

TWENTY-SEVENTH ANNUAL MEETING

Western Cooperative Spray Project

Imperial Hotel, Portland, Oregon

January 21, 22, 23, 1953

The twenty-seventh annual meeting of the Western Cooperative Spray Project was held in the Green Room of the Imperial Hotel, Portland, Oregon on January 21, 22 and 23, 1953. The conference membership is composed of State, Federal and Dominion entomologists, pathologists and chemists engaged in research or extension work on the control of fruit insects and diseases in California, Colorado, Utah, Idaho, Montana, Oregon, Washington, British Columbia and Alberta.

H. S. Telford was chairman and L. G. Gentner secretary of the conference. January 21 and 22 were closed sessions and January 23 was open to members of industry. Discussion leaders were as follows: V. W. Olney for insects attacking apples and pears; Ted Anthon, pests of stone fruits; J. R. Kienholz, fruit diseases; D. B. Waddell, spray dispersal equipment and L. C. Terriere, spray residues.

W. T. Sumerford of the Wenatchee Laboratory of the Public Health Service gave an illustrated talk on economic poisons and the work of the laboratory in safeguarding human health.

The discussion leaders presented summaries of the 1952 research work to members of industry at a luncheon session held in the Green Room of the Imperial Hotel on January 23.

Members elected to office for the coming year were: H. S. Telford, *Chairman;* M. R. Harris, *Co-Chairman;* V. W. Olney, *Secretary;* and J. R. Kienholz, *Co-Secretary.*

The 1954 meeting will be held on January 20, 21 and 22 at the Imperial Hotel, Portland, Oregon.

Central International Forest Insect and Disease Conference

On January 6 and 7, 1953, forest entomologists and forest pathologists of Minnesota, Michigan, Wisconsin, Ontario, Manitoba and Saskatchewan met at the University of Minnesota, St. Paul, Minnesota to participate in a pioneer meeting of the Central International Forest Insect and Disease Conference. The morning of January 6 was devoted to organizational matters, and the remainder of the meeting period was spent in outlining problems and work in progress at the forest insect and disease research centers throughout the area from which representation was obtained.

Participating in the initial meeting were Dr. J. A. Beal, Chief, Division of Forest Insect Investigations, USDA; Dr. J. R. Hansbrough, Senior Pathologist in Charge, Division of Forest Pathology, USDA (New Haven Laboratory); Dr. M. L. Prebble, Chief, Division of Forest Biology, Department of Agriculture, Ottawa; and Dr. J. E. Bier, Associate Chief, Division of Forest Biology. The following laboratories, Universities and State agencies concerned with forest insect and disease problems were represented.

Departments of Conservation (Michigan, Wisconsin, Minnesota)

Universities (Minnesota, Michigan, Michigan State College, Wisconsin, Toronto)

Offices of State Entomologist (Minnesota, Wisconsin)

Canadian Department of Agriculture, Laboratories of Forest Biology (Saskatoon, Indianhead, Winnipeg, Sault Ste. Marie, Toronto)

U. S. Department of Agriculture (Forest Insect Laboratory Region 9, Division of Forest Pathology)

It was unanimously agreed that future meetings should continue to stress informal discussions of common problems and research approaches of the various workers who are trying to cope with them.

Dr. Blair M. McGugan, Division of Forest Biology, Science Service, Canadian Department of Agriculture, Forest Insect Laboratory, Sault Ste. Marie, Ontario, Canada was chosen chairman of the group for the ensuing year. It was agreed that the next annual meeting will be held at the Laboratory of Forest Biology, Sault Ste. Marie, Ontario in October, 1953.

James W. Butcher
Chairman, Central International Forest Insect and Disease Conference

Interdepartmental Committee on Pest Control

The Interdepartmental Committee on Pest Control held its seventeenth regular meeting on March 27, 1953 at Washington, D. C. and agreed upon the following release:

1. A Statement on the Health Hazards of Insecticide Vaporizers Used as Fumigators for the Control of Insects

"Because of the health hazard inherent in the misuse of insecticide vaporizers as so-called fumigators, the Interdepartmental Committee on Pest Control recommends against their use in living quarters."

2. Coumachlor—A coined name for the rodenticidal chemical 3-(alpha-acetonyl-4-chlorobenzyl)-4-hydroxycoumarin

"Coumachlor" is a coined name selected for the rodenticide 3-(alpha-acetonyl-4-chlorobenzyl)-4-hydroxycoumarin and approved by the Interdepartmental Committee on Pest Control. The Interdepartmental Committee secured the following information from the sponsor of this coined name and takes no responsibility for the contents thereof.

Rodenticides containing this compound have previously been referred to as Tomorin and as Geigy Rodenticide Exp. 332.

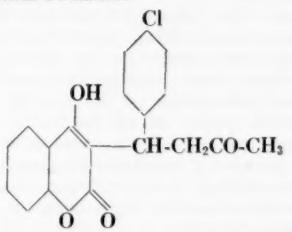
Approval of the name "coumachlor" by the Interdepartmental Committee on Pest Control implies that the name is available for free use in designating the pure chemical 3-(alpha-acetonyl-4-chlorobenzyl)-4-hydroxycoumarin.

The name "coumachlor" applies to the pure chemical. A purified product, which contains a minimum of 98% of the pure compound, is used in the formulation of bait concentrates.

Physical and Chemical Properties

Empirical Formula: $C_{19}H_{15}O_4Cl$

Structural Formula:



Data on the pure substance and the purified product are tabulated as follows:

	Pure	*Purified*
Color	White	White
Form	Crystalline	Crystalline
Odor	None	None
Melting Point (Kofler-Bank)	169–171°C.	163–168°C.

Solubility

Coumachlor is practically insoluble in water, slightly soluble in benzene and ether, soluble in methanol, ethanol and isopropanol, and very soluble in acetone and chloroform.

Coumachlor is a relatively stable compound. When combined with material such as cereal in finished baits, it retains its toxicity to rodents over a relatively long period of time.

Physiological Properties

Coumachlor has anticoagulant properties similar to dicumarol. Extensive experiments indicate that when combined in concentrations of 0.025% with suitable bait materials it is effective in controlling commensal rats and mice. When such baits are ingested in daily repeated dosages, their anticoagulant action begins to cause death in 3 to 6 days. According to the 1952 Annual Report of the Rodent Control Committee, National Pest Control Association, Inc., an average of 9 mean days was required to completely clean out infestations of both Norway and roof rats while an average of 14 mean days was required to eliminate infestations of house mice with coumachlor baits. Mr. D. Glen Crabtree, of the U. S. Fish and Wildlife Service, concluded that at concentrations of 0.025% coumachlor in cereal baits " . . . will control commensal rats and mice when employed under conditions conducive to normal bait acceptance and when adequate amounts of bait are exposed."

Unlike some rodenticides used previously in baits, rats and mice do not develop bait shyness to coumachlor. In fact, affected rats and mice frequently continue to feed until they are no longer able to walk to the bait stations.

In an unpublished report, the Hazleton Laboratories show that fowl are less susceptible than mammals although all species of small animals tested were susceptible to the toxic effects of coumachlor when fed sufficient dosages over a period of several days.

Massive quantities of prepared bait must be consumed to induce acute symptoms from a single dose and the hazard from acute poisoning is correspondingly slight.

The hazards to human health involved in the use of coumachlor are much less than with some of the rodenticides previously employed. Since repeated ingestions are usually required to cause death in animals, the likelihood of such ingestions accidentally is remote. However, if hemorrhages result from accidental ingestion by humans, blood transfusions combined with intravenous and oral doses of Vitamin K are indicated.

Analytical Methods

A spectrophotometric method of analysis is available for coumachlor. This may be obtained from the Geigy Company, Inc.

S. W. Simmons, *Chairman*
Technology Branch,
Communicable Disease Center,
U. S. Public Health Service,
50 Seventh Street, N.E.,
Atlanta 5, Georgia
M. Alpert, *Secretary*
Chemistry Branch,
Bureau of Ships,
Department of the Navy,
Washington 25, D. C.

BOOK REVIEWS

HUMAN FACTORS IN AIR TRANSPORTATION: OCCUPATIONAL HEALTH AND SAFETY, by Ross A. McFarland, Ph.D. 1st Edition, 1953. McGraw-Hill Book Co., Inc. New York, Toronto, and London, pp. i–xv, 1–830, illus., refs. Large octavo, $13.00.

Entomologists concerned with the problems which arise as a result of the development of air transportation will find valuable information and useful critical discussion in this book. Of particular interest in this regard is Part VI, which devotes eighty pages to a consideration of sanitation and health in airline operations.

In a chapter on the sanitary control of airports and ground facilities, attention is given to entomological and other aspects of such problems as: factors governing the selection of airport sites; sewage and waste disposal, including basic principles in control measures directed against vectors, pests and rodents; health problems in a tropical air route, with especial reference to malaria, its sanitary control, and the evaluation of malaria-prevention programs; evaluation of health and sanitation on international air routes, including the importance of reliable up-to-the-minute information on local prevalence of disease and disease-vectors; and the administrative control of sanitary programs.

The chapter which deals with health and quarantine regulations in air travel, and their influence upon the free flow of traffic, brings out such important facts as (1) the speed with which diseased persons, infested cargoes, or dangerous vectors or pests can be transported, as well as (2) the need for revising many existing quarantine and customs procedures which were primarily developed for the control of the much slower maritime and other surface traffic. The factors of speed and range, peculiar to modern aircraft, have introduced problems which must be considered in the development of new regulations and procedures.

Detailed attention is given to such matters as: the development of sanitary codes and conventions for aerial navigation; transportation of disease by human beings during the incubation period; transportation of arthropod vectors; and transportation of disease by small animal hosts. The use of insecticides on airplanes is discussed with respect to choice of insecticide, time of application and methods of spraying, the advantages and disadvantages of permanently installed automatic spraying systems, and the reactions of passengers to sprays.

In discussing the dissemination of insects and pests of agricultural importance, the author points out that their transportation by air craft is almost as great a problem *within* such countries as the United States as it is *between* countries. Several important ways in which plant pests may be transported on aircraft are illustrated by concrete examples. The problem of inspection of cargo and baggage at ports of entry is treated, and the author brings out reasons why the control of agricultural pests is often more difficult than that of fectors of human disease. The aerial dispensing of insecticices at airports and in their vicinity is discussed as one of the methods designed to prevent the transportation of insects from one place to another. Finally, the functions of the traffic, medical, and operating departments are discussed with regard to their part in the implementation of specific control procedures.

Each chapter is closed with a summary and a carefully selected bibliography.

The book as a whole is a definitive work, the result of painstaking research and creative thought. The specialist will be pleased to find that it is not an uncritical compilation, but rather that mature judgment has resulted in a wise selection of subject matter, supported by sound factual information. Proper emphasis is wisely placed. There is unusually good coordination of a wide variety of topics to make a coherent and well-related whole. McFarland's scholarly book will appeal to the student of human ecology, and by reason of its down-to-earth treatment (despite the subject!), it will be suited to the needs of those eminently practical people, the entomologist and the public health worker.

HENRY S. FULLER, M.D.

A MANUAL OF ENTOMOLOGICAL TECHNIQUES, by Alvah Peterson, Ohio State University, Columbus 10, Ohio. 7th Edition, 367 pp. Lithoprinted by Edwards Brothers, Inc., Ann Arbor, Michigan, April, 1953. Order from the author. $7.50.

This publication is an extensive revision of the sixth edition of "A Manual of Entomological Equipment and Methods," parts 1 and 2. It includes all of the figures and most of the tables found in the sixth edition.

NEW MATERIAL.—*Figures and Tables.* There are 22 new plates of figures making a total of 182 plates. They contain chiefly figures and photographs of new biological techniques; namely cages, containers, and equipment for rearing, devices for collecting and trapping, gadgets for museum work and miscellaneous materials. New tables of information, chiefly on humidity, are included.

Discussions. The following topics are discussed, some in considerable detail: measuring ecological factors (temperature, humidity, air velocity, evaporation and light); cage microclimates; materials for cages; general information on the rearing of insects and mites with specific details for mass rearing of 50+ common species; marking insects; collecting, killing and preserving immature stages and adults; some common killing, fixing, clearing, staining and mounting fluids or media; suggestions for drawings and miscellaneous notes.

This handbook is of special interest to students and teachers. It is a useful guide for courses or subject matter dealing with or presenting techniques. Investigators, especially beginners or others who are starting new projects, will find much helpful information throughout the volume. Also a close examination of the contents may suggest new ideas to seasoned research workers.

F.W.P.

APHIDS OF THE ROCKY MOUNTAIN REGION, by Miriam A. Palmer. The Thomas Say Foundation, Vol. 5, 1953. A. B. Hirschfeld Press, Denver, 6×9 inches, 452 pp. 455 figures plus 8 colored plates. $10.25.

No aphidologist in North America could well get along without this volume. Entomologists generally will find it to be their most up to date and useful reference. This study primarily includes Colorado and Utah, southern Wyoming, southeastern and south-

ern central Idaho and northern New Mexico. However, this study includes keys to most of the economic species of aphids known to occur in North America. The general entomologist, as well as the beginner, will find the figures and discussions dealing with the family, and the distinguishing characters used for recognition, to be clearly shown and concisely explained. The general aphid life cycle and characteristic life history are brought out. Collecting and shipping methods are given. Excellent keys have been prepared. These permit separation of the nearly 460 species from family to subfamily, tribe, genus and species. In addition to the general keys in the body of the text, 23 pages of additional keys are given to the species of aphids commonly infesting economic plants of the region. These keys will be found to constitute a great convenience. Each key deals with a specific host or hosts. The aphids of the region all are listed under host plant. This listing is the first to include a large number of species described since 1935, up to which time the (1938) Patch "Food-Plant Catalogue of the Aphids of the World" reports. In excellent figures, Professor Palmer clearly sets forth the taxonomic characters of the various species of aphids recorded from the region up to 1950, from both introduced and native host plants. The figures are a part of the carefully prepared description which is given, plus life history notes, for each species. The plan of classification followed is largely that of A. C. Baker (1920). A conservative attitude is shown with regard the status of species doubtfully distinct, where insufficient specimens and inadequate biological data are available to justify reliable conclusions as to synonomy. In certain cases, additional collections may suggest the need for combining certain species, or further material may indicate more distinct differences than now are evident. The present volume is a substantial enlargement, both as to species considered and geographical area involved, over "The Aphidae of Colorado" by Gillette & Palmer, thet hree parts of which were published in 1931, 1932 and 1934, containing 333 species. Professor Palmer had worked with aphids of this region for 40 years, when this volume was completed in 1952. For 27 years she worked on the project with Dr. C. P. Gillette. She then conducted the project independently for the next 13 years. This new work includes more than 100 additional species, enlarged and improved keys, many additional figures, and the nomenclature has been brought down to date. Anyone interested in the study of aphids, or faced with the need to recognize economically injurious or virus-vector species, would do well to have access to a copy of this new and excellent book.

G. F. KNOWLTON

PESTICIDE HANDBOOK—1953, by Donald E. H. Frear, College Science Publishers, State College, Pa. 5th ed., 204 pp. $1.25.

The fifth (1953) edition of Frear's Pesticide Handbook lists in Section I the trade names of 5,017 products as compared to 4,360 in the fourth edition. The active ingredients of each product are given.

In Section II, all products are listed according to uses and active ingredients, such as adjuvants, animal repellents, diluents, fungicides (dusts and sprays), herbicides, insecticides (aerosols, animal dips, baits, concentrates for manufacturing, dusts, fumigants, mothproofing materials, screw worm smears, sprays, paints and polishes), pesticide equipment, plant hormones, rodenticides, seed treatments and wood preservatives.

Section III contains a list of commercial pest control operators arranged alphabetically by state.

In Section IV all manufacturers are listed alphabetically with reference, by number, to their products in Section I.

Information is presented on antidotes for poisons, types of pesticides and general uses, compatibilities and hazards of the common pesticides, rates of application and miscellaneous measures.

No other pulbication gives as much information on trademarked pesticides. Frear's pesticide handbook is indispensable to the economic entomologist, plant pathologist and pest control operator seeking to control injurious insects, fungi, weeds and rodents with chemicals.

R. C. ROARK

THE NATURE OF VIRUS MULTIPLICATION, edited by Sir Paul Fildes and W. E. VanHeyningen. 320 pages. Cambridge University Press. 32 East 57th St., New York 22, N. Y. (1953). $6.50.

The papers presented in this book were originally given as a symposium sponsored by the Society for General Microbiology at Oxford, England 1952. The contributors and subject matter include: *Chantrenne* Problems of protein synthesis; *Bowden and Pirie*, Virus multiplication as a form of protein synthesis; *Bauer*, Metabolic aspects of virus multiplication; *Luria*, An analysis of bacteriophage multiplication; *Boyd*, The role of mutation in the survival and multiplication of bacterial viruses; *Lwoff*, The nature of phage reproduction; *Latarjet*, The multiplication of bacterial viruses studied by radio-biological methods; *Fildes, Kay and Soklik*, Divalent metals in phage production; *Gard*, Aspects of formation of incomplete virus; *Hoyle*, The multiplication of the influenza virus considered in relation to the general problem of biological multiplication; *Flewett*, Growth of viruses of the influenza group as revealed by electron microscopy of infected cells; *Fulton*, The argument for a venerable hypothesis of virus multiplication; *Bergold*, The multiplication of insect viruses; *Carr*, The multiplication of fowl tumour viruses; *Sanders*, Possible multiplication cycles in neurotropic viruses.

Each paper is very well documented particularly with recent work and after each a discussion is included whereby other members of the symposium discuss merits of the material presented. Most papers contain tables and graphs and some are very well illustrated by photographs. The authors' concepts are based on experimental data, but there also has been an attempt to correlate information from one area into another and look ahead at the total problem. This is useful because in some fields the nature of virus synthesis has become clearer than in others. Present concepts and possible theoretical alternatives are well presented. This is a very useful book for one to gain a challenging overall perspective of virus multiplication based on present knowledge.

JOHN R. KELLER

CLASSIFIED

Advertisements of commodities for sale or exchange or of services will be entered at 50 cents per issue or $2.50 per year. Advertisements requesting information for use in publications will be charged at the rate of $1 per advertisement to run as long as space permits. Send notices and cash in advance to Ernest N. Cory, College Park, Md., by the 15th of the month preceding publication.

FOR SALE: Journal of Economic Entomology, six (6) complete volumes 38 (1945) to Vol. 43 (1950) inclusive @ $3.00 per volume; eight (8) single numbers, Vol. 44, #1; Vol. 43, #1, 3, 4, 5, 6; Vol. 41, #3; Vol. 33, #2, @ .50¢ per single copy. H. Eldon Scott, Specialist in Entomology, Extension Service, State College Station, Raleigh, North Carolina.

SITUATION WANTED: Entomologist with M.S. degree. Four years Agricultural Pest Control experience with national food processing company. Interested in research-extension type work, preferably in East. Married veteran, references on request. Reply to Box C, Entomological Society of America, University of Maryland, College Park, Maryland.

SITUATION WANTED—Teacher desires position in sales or contact work with reliable firm. Background—B.S. University of Massachusetts in Entomology and General Agriculture 1948, four summer sessions Cornell University, five years teaching experience vocational agriculture, Married, veteran, excellent references. Robert H. Clorite, Reservoir Road, Highland, New York. Phone: Highland 4387.

POSITION WANTED: by economic and medical entomologist (recent Ph.D.) with fifteen years experience in practical economic and public health entomology and field research. Desires position teaching and/or experiment station work. Please correspond care of Box *A*, American Association of Economic Entomology, College Park, Maryland.

PICTURES AND PHOTOGRAPHIC SERVICES AVAILABLE. Color sound 26 minute movie "Garden Insects." Color silent movie "Fruit Insects" without titles. Wide selection of color slides. 8 x 10 black and white pictures for advertising or editorial use. Insect movies a specialty. Let me know your needs. Lee Jenkins, Entomologist, Polo, Missouri.

MANAGERS WANTED—World's largest pest control firm needs several high-caliber men for responsible positions. Must have initiative, good judgment, the ability to work and deal with people, and should be personally ambitious. Experience in professions related to pest control helpful. Liberal salary and incentive arrangements provide excellent opportunities with progressive and well-established firm. Employee benefits include paid vacation, sick leave, life insurance, hospitalization, and pension plan. Training programs for our future managers and other supervisory positions also open to college graduates. All replies confidential. Contact Technical Department, Orkin Exterminating Company, Inc., 713 W. Peachtree Street, N.E., Atlanta, Georgia.

FOR SALE. "Unbidden House Guests" 540 pages, 400 pictures, close-out $5.30 Prepaid. Send check to Hartnack Publishing Co. Post Office Box 668, Tacoma, Washington.

POSITION WANTED—by entomologist. Ph.D. Biochemistry minor. Many years teaching and research experience. Publications. Desires academic appointment with teaching and research. Prefer Middle West. Major research interests are insect toxicology and radioactive tracer work. Now located at a Western College, available after December. Please correspond care of Box B, American Association of Economic Entomologists, College Park, Maryland.